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SALMON FISHERY DIAGRAMS

Figure 1. Schematic of the Salmon Fishery.

The term, races (demes), denotes individual spawning aggregates, and 1^{o} Production (first degree salmon production), denotes the first life cycle stage beyond the egg (fry). (Adapted from Mundy and Mathisen 1981).

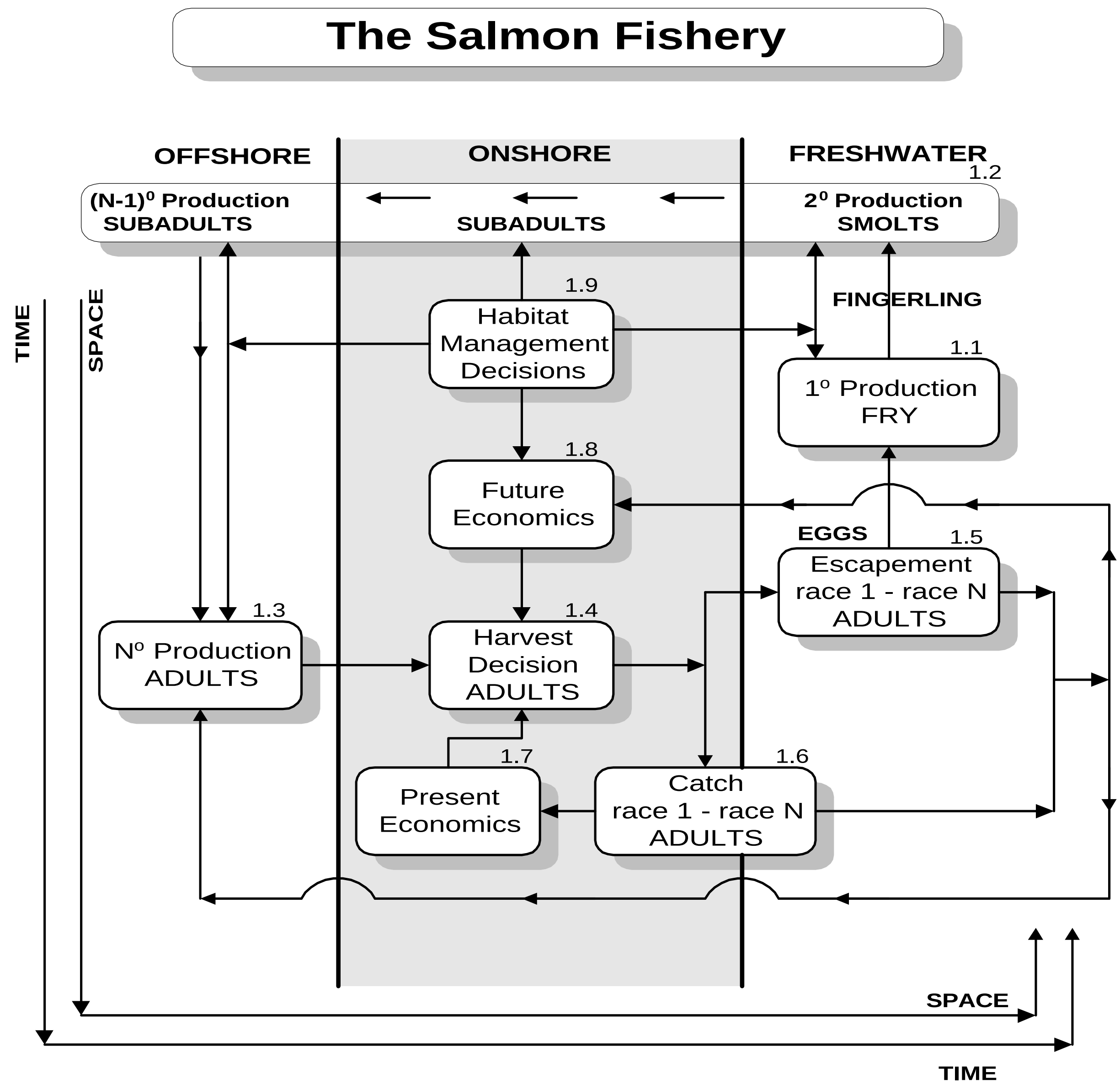
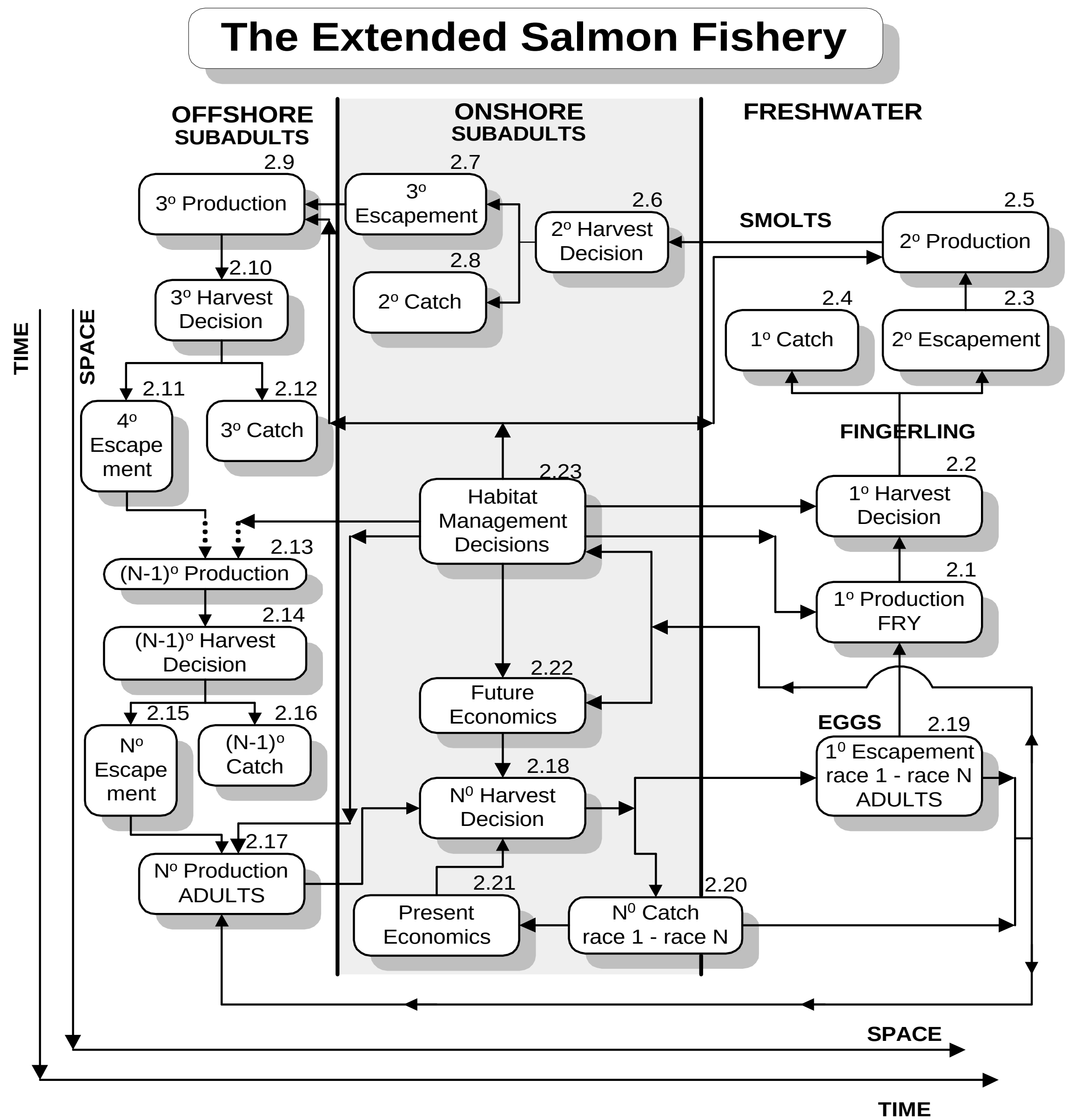


Figure 2. Schematic of the Extended Salmon Fishery.
The term, races (demes), denotes individual spawning aggregates, and 1^{o} Production (first degree salmon production), denotes the first life cycle stage beyond the egg (fry). (Adapted from Mundy and Mathisen 1981).



PRINCIPLES FOR SUSTAINABLE SALMON MANAGEMENT

Table 1. Principles for sustainable salmon management

Principle I. Protect wild salmon and its habitat in order to maintain resource productivity

Principle II. Maintain escapements within ranges necessary to conserve and protect potential salmon production and to maintain normal ecosystem functioning

Principle III. Harvest salmon in a manner consistent with the degree of uncertainty regarding the status and biology of the resource

Principle IV. Establish and apply an effective management system to control human activities that affect salmon

Principle V. Maintain public support and involvement for sustained use and protection of salmon resources

PREFACE

From those in occupations already subject to uncertainties of weather, production and markets, it is reasonable to expect concern about any document, or process, that may contribute to changes in salmon fishing regulations. Salmon harvesters are often caught in the dilemma where the need for rigorous application of science to management is accepted as essential for long-term conservation of the resources, but where indiscriminate application of the same conservation science is rejected because it threatens loss of culture and livelihood. In developing the basis for the principals and criteria, care has been taken to separate public policy from conservation science in order to minimize concerns about potential impacts on those communities and people who rely on salmon fishing for food, culture, and livelihood.

The principles and criteria are intended to support Alaska's public involvement process by distinguishing between concepts that are scientifically feasible and desirable, and the public policy process of choosing whether, and how, to implement those concepts. Alaska has a strong public involvement process for salmon management, and a high level of understanding and awareness of fisheries matters among political leaders. It is in the policy arena where salmon harvesters have opportunities to see that conservation science is equitably applied to the resources on which cultural and economic well being depend.

The principles and criteria are inclusive of all existing Alaskan salmon fisheries. It is possible for any existing Alaskan salmon fishery to be managed in accord with the principles and criteria of sustainable salmon fishing. The extent to which the elements of any present Alaskan fishery may adhere to the principles is expected to vary according to the historical circumstances of the fishery. Nonetheless the principles and criteria can be implemented for any salmon fishery targeting any group of salmon stocks or species, although the technical challenges and expense of conforming to the principles will vary by fishery.

Phil Mundy
Lake Oswego, Oregon
July, 1998

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Special recognition is due the Chair of the Alaska Board of Fisheries, John White, and his subcommittee of board members, Grant Miller and Larry Engle for their many hours of work and leadership in the public involvement process. The efforts of the members of the public who served in the Board's review process are much appreciated. In the Office of the Commissioner of Fish and Game, Rob Bosworth coordinated and lead the peer review efforts for the department, and Geron Bruce facilitated the final peer review. Thanks to all the unnamed members of the Alaska Department of Fish and Game who contributed their ideas and other help to this work.

INTRODUCTION

The State of Alaska commissioned this work as an essential step in the development of a framework for evaluating how its programs contribute to the sustainable management of salmon. As an independent assessment, its purpose is to adapt the principles and criteria of sustainable resource management to salmon, and to identify the published scientific information on which they are based. The principles and their criteria thus represent a compendium of advice on sustainable resource management from scientists all over the world.

Natural resource management has been defined as shaping human behavior to enable the persistence of the exploited portions of ecosystems (Mundy 1996). As used here, the concept of sustainable fishing means harvesting salmon and managing critical habitats to secure the human uses and natural functions of the salmon resources and their ecosystems in perpetuity. Sustainable salmon management is a process wherein fisheries and habitat regulators assume the responsibility to limit human uses to those that do not harm long-term utilities of natural resources. Within this definition managers are required to assemble and use a sound factual basis in making their management decisions. In the sustainable context, managers preserve the expectation of future utility of the salmon resources for the full range of human uses and ecological functions. The elements of the factual basis for sustainable salmon management actions are among the key criteria for sustainable salmon management principles.

The principles and criteria form a sounding board against which the many professionals who harvest, process, market and regulate salmon in Alaska may test their own concepts and practices of sustainable salmon management. Although intended to inform all concerned parties, the work is primarily a reference for scientists, administrators, and policy makers who manage salmon harvests. Every effort was made to explain concepts in plain language, however the precision of scientific concepts was not sacrificed in the process. Definitions of scientific terms and concepts are presented at the end of the document.

Care has been taken to separate matters of public policy from science. The principles and criteria, and any subsequent fishery evaluation framework that incorporates them, cannot prescribe how the allocation of the benefits and burdens of conservation is to be accomplished. Identifying the scientific boundaries of sustainable salmon fisheries is necessarily separated from the political process of implementing sustainable salmon management. The reader is advised to take care to distinguish the process of gathering and tendering the best scientific advice from that of allocating the burden of conservation. The principles and criteria that support a fishery evaluation framework in Alaska's public involvement process need to distinguish between concepts that may be scientifically feasible and desirable for resource conservation, and the public policy process of choosing whether, and how, to implement those concepts.

Why does Alaska need principles and criteria of sustainable salmon management? First, the task of approaching the management of a resource of such enormous biological diversity and geographic complexity needs to be put on a systematic basis. Although the success of the State of Alaska in managing major, commercially important salmon stocks originating in Alaska is certainly well established, most of the Alaskan salmon spawning aggregates, by locality, have had no long-term systematic monitoring of the status of spawning populations. Second, transient salmon stocks from Canada and the contiguous United States inevitably impact the operations of Alaskan fisheries, particularly in southeastern Alaska, but in all transboundary situations. The negative impacts on Alaskan salmon fisheries are most severe when the transient salmon stocks have not been sustainably managed in their home watersheds. In demanding that its neighbors behave responsibly, it is important for Alaska to establish, and to assert its own principles and criteria for sustainable salmon management. Finally, a level playing field for salmon management principles and criteria across salmon fisheries should help policy makers identify and define fisheries policy issues, as separate and distinct from fisheries science issues.

In a historical context, the formal definition of principles and criteria for sustainable salmon fishing is the next logical step in the long-term process directed toward the protection and sustained use of salmon resources in the State of Alaska. Since statehood, public policy of the State of Alaska has been committed to protection and sustainable use of Alaska's wild salmon stocks, as explicitly required in the state constitution (Cooley 1963; Krasnowski 1997). Salmon management and enhancement programs have been generally successful at conservation of wild stocks within Alaska to the extent that those objectives have been measured (Thomas 1993; Baker, Wertheimer et al. 1996; Holmes and Burkett 1996; Wertheimer 1996). Even though Alaska has many examples of successful salmon management, it is important to note that localized extinctions (extirpations) of salmon runs have occurred due to human development of Alaska (Baker et al. 1996).

Not even Alaska is immune to the loss of salmon through destruction of salmon habitat. As the processes driven by human population growth continue to take their toll on Alaskan salmon habitat, it is timely to formally state principles and criteria to guide sustainable salmon management in an era when risks to long-term salmon population viabilities are increasing. Fortunately for a work of this nature, there is a substantial scientific literature base on which sustainable management principles and criteria can be based.

Long-standing concepts of sustainable natural resource management have been rediscovered, critically refined, expanded, and made operational within the last twenty years (Holling 1978; Walters 1986; Naiman and Stouder 1996). Since Pacific salmon entered the domain of the U.S. Endangered Species Act in 1990 (Mills, McEwan et al. 1996), the basic concepts of salmon management have been frequently challenged and critically re-examined (NRC 1995; Waples 1995; Mundy 1996; NRC 1996). Literature concepts on sustainable natural resource management have now converged to the point where the scientific basis for salmon management is well on its way to a new paradigm.

The Emerging Salmon Management Paradigm

The body of literature on how to approach sustainable fisheries management is rapidly growing (Naiman and Stouder 1996; NRC 1996; Mooney 1998). One factor in this rapid growth appears to be dissatisfaction and frustration among resource management professionals with the outcome of historical management programs for many exploited wild plant and animal species (Hofman and Powell 1998; Lauck, Clark et al. 1998). Attempts are increasingly being made to move from single-species management toward multi-species approaches, and toward incorporating many more elements of the ecosystem in fisheries management (Fujita, Foran et al. 1998; Hofman and Powell 1998; Jarre-Teichmmann 1998).

Those involved in the process of salmon management need to be aware that a growing portion of the scientific community is deeply dissatisfied with the science of salmon fisheries management, as it has been practiced in the past (NRC 1996). For example,

> An overriding focus on extraction of biomass and numerical goals in fishery management has promoted the depletion and biotic impoverishment of the Pacific salmon ... resource. The prevalence of mechanistic thinking has marginalized or excluded critical ecological and cultural functions that sustain the resource and embody much of what humans value about it. This approach to salmon management has led to its own demise. (P. 411) (Frissell, Liss et al. 1996).

Although this epitaph may be premature in the case of Alaska, (Baker, Wertheimer et al. 1996; Wertheimer 1996), it is applicable to a growing suite of sport and commercial salmon fisheries in the contiguous northwestern United States and Canada (Nehlsen, Williams et al. 1991; Huntington, Nehlsen et al. 1996; Hyatt 1996; Mills, McEwan et al. 1996; Slaney, Hyatt et al. 1996). In a fisheries context the definition of conservation is changing from maximizing yield for single stocks toward encompassing, " ... the protection, maintenance and rehabilitation of native biota, their habitats, and life-support systems to ensure ecosystem sustainability and biodiversity. " (p. 1587) (Caddy 1995). The general rationale for fisheries conservation from a broad perspective appears to be converging on enabling long-term harvests within the context of protecting the health of the ecosystem (Fujita, Foran et al. 1998). Indeed, conservation principles for sustainable fisheries management appear to be converging on the generic purpose of maintaining ecosystem function and processes (Starnes, Jiminez et al. 1995), see Appendix Table 7 (A - 8); (Olver, Shuter et al. 1995), see Table A - 7; (FAO 1995), see Tables A - 5 and A - 6; (MSC 1996), see Tables A - 3 and A - 4. Even given this emerging consensus on the purpose and means for conservation, there is no world-wide agreement on the causes for collapse of fisheries, nor on solutions (Caddy 1995).

Solutions enabling long-term sustainable salmon management are likely to come from understanding how climate and physical oceanographic processes combine to determine marine and freshwater survivals. The theme of understanding the role of the physical environment, including climate, in the regulation of fish abundance is a very old concept (Cushing 1982) that now has the benefit of a large global data base, and over a century of investigation. Perhaps the most critical aspect to an understanding of the effects of environment on fish stocks is the interaction between time and space scales (Walters 1996b; Hofman and Powell 1998). Processes that occur over very brief time periods, such as harvest of adult salmon or the spring plankton bloom, can have profound short-term consequences for abundance. Long-term, large scale processes, such as trends in climate, also have serious consequences for salmon production (Beamish and Bouillon 1993; Francis and Hare 1994; Pearcy 1996). The conjunction of long-term and short-term effects can provide for sharp changes in abundance of fish stocks, as seen in many parts of the world (Hofman and Powell 1998). Thus the ability to understand and to forecast the behavior of natural systems, particularly in the marine environments, is dependent on the time the scales involved (Steele 1998).

Biological and physical approaches alone are not sufficient for sustainable salmon management (NRC 1996). Solutions enabling long-term sustainable salmon fishing and ecosystem protection also require institutions and property rights regimes appropriate to the nature of both the ecosystem and the human users (Hanna 1998). Property rights are the collections of entitlements that define the rights and responsibilities of user of the resources. The institutions capable of supporting the salmon in its ecosystem need to be capable of attaching value to both the services and the commodities, such as tourism and commercial fishing, provided by the ecosystem. Finally, and perhaps most importantly, the institutions of ecosystem management need to be able to coordinate user groups and managers on the geographic scale of the ecosystem (Hanna 1998).

Framing institutions capable of supporting the salmon in its ecosystem is a matter of integration and coordination. Sustainable salmon management requires the integration of the many small-scale institutions and private and public land and water users (Lee 1996b). Collaboration among users, as well as among institutions at all levels of government is a key principle of salmon management (Lee 1996).

Can the existing institutions of salmon management satisfy the interests and needs of user groups over a wide enough geographic area to provide for sustainable salmon management? The information that follows is an attempt provide the bounds within which salmon management institutions may be able to provide sustainable populations of salmon for all users, for any purpose. Within the bounds of the principles and criteria, the policy process is grounded in the science of sustainable salmon management as it attempts to forge the laws, regulations and institutions that can successfully balance the entitlements of the users against the survival of the resource.

DESCRIPTION OF THE SALMON FISHERY

The elements of the salmon fishery are described in relation to the salmon's life cycle and habitats to provide a frame of reference for the principles and criteria. The Salmon Fishery (Figure 1), and the Extended Salmon Fishery (Figure 2) visually define the basic elements (boxes in Figures 1 and 2) of a sustainable salmon harvest management program in order of the salmon life cycle (eggs, fingerling, smolts, subadults, and adults), as superimposed on the habitats (freshwater, onshore, and offshore) critical to completion of the life cycle. The elements (boxes, Figures 1 and 2) occur as cycles in time and space (Mundy and Mathisen 1981). The long period cycle is the complete life cycle within which occur shorter period cycles of harvest, habitat management and economics. The Salmon Fishery (Figure 1) reduces salmon management programs to nine basic elements, and the Extended Salmon fishery (Figure 2) has twenty-three elements for the sake of illustration, but the actual number would depend on the situation.

The elements in the basic harvest management cycle are defined as production estimation (i.e. boxes 1.3 and 2.17), harvest decision (i.e. boxes 1.4 and 2.18), escapement (i.e. boxes1.5 and 2.19) and catch (i.e. boxes 1.6 and 2.20) after Mundy and Mathisen (1981). Note that the National Research Council called the contents of box 1.3, “stock assessment,” “management plans,” and “evaluation,” and box 1.4 “conducting the fisheries” (Page 294) (NRC 1996). Habitat management cycles (boxes 1.9 and 2.23) start at the end of each life cycle and have periods of variable length. As is the case with harvest cycles, the consequence of habitat management cycles feed forward from one generation into the next. Economic elements (boxes 1.7, 1.8 and 2.21, 2.22) are cyclic, with the present economic element cycling at the same period as the harvest, and a future economic element cycling with the same period as the life cycle. Within the context of a series of linked habitats, the elements of the life cycle repeat with a time period of an average salmon generation, and the lengths of harvest cycles are on the order of days or weeks. The average salmon generation is usually from two to five years.

The two- to five-year cycle, or generation-length cycle, of the salmon fishery contains other cycles that “feed back” the results of present actions to control the options available for future actions. The feed back pathways are indicated by the arrows in Figure 1. In the generation-length cycle, a concept of the production (boxes 1.1 - 1.3) defines the yield available to harvesters (total annual landings), and it drives an initial decision on harvest (box 1.4) that results in the salmon run being converted to (spawning) escapement (box 1.5) and catch (target and non-target landings plus collateral mortality) (box 1.6) in the case of a decision to open the fishery. If the harvest decision is negative the production is converted into escapement. In the shorter cycles that occur during the harvest season, information on the numbers of salmon caught and escaping the fishery to spawn is fed back throughout the harvest season to the filter of present economic conditions (box 1.7) and the in-season production estimate (box 1.3) to the harvest decision point (box1.4). The harvest decision cycle (boxes1.3 through 1.7) is repeated as often as landings and escapement data are reported until the end of the migration season, or run. Habitat management decisions (box1.9) act to improve or reduce the production realized from each run of salmon throughout the life cycle. Market conditions during (Figure 1, box 1.7) and between (Figure 1, box 1.8) fishing seasons may limit the ability of managers to control harvest. Price disputes or processor limits during the season may cause reductions in total fishing effort. Between

fishing seasons market conditions may change the rate at which the average fishing vessel can catch salmon and influence investment in processing capacity.

The four basic elements of the harvest management cycle (boxes1.3 - 1.6) are repeated in time and space in the Extended Salmon Fishery to represent the full range of situations encountered in Alaskan salmon fisheries (Figure 2). Conceptually the Extended Salmon Fishery is series of forward run reconstructions (Starr and Hilborn 1988; Mundy, English et al. 1993) for a cohort of salmon. The extended model recognizes that harvest of most, if not all, Alaskan salmon stocks occurs at several different points in the life cycle at a number of different localities. While the Salmon Fishery model lumps all the cohorts appearing in a fishery, the extended derivative works on a single cohort with the cohorts being summed for a brood year. Note the pivotal role of habitat management decisions (box 2.23) is the same as in the Salmon Fishery. Freshwater habitat management decisions include implicit harvest decisions for eggs, fry and fingerlings, as illustrated by the connection between boxes 2.23 and 2.2. Habitat management decisions in coastal and offshore habitats impact production throughout the life cycle.

While the Salmon Fishery contains only a single harvest event, the Extended Salmon Fishery has multiple harvest events. In the onshore marine environment early in the life cycle, an example of the secondary harvest decision for the cohort would be the permissible levels of juvenile salmon bycatch (Figure 2, box 2.6). In the presence of bycatch accounting programs (box 2.8) with stock identification, the consequences for future salmon production (box 2.7) can be specified to the extent permitted by the resolution of the stock identification program. Harvest control at the secondary level (box 2.6) consists of bycatch avoidance procedures, with the objective being to minimize salmon bycatch. The ideal for sustainable salmon management is to quantify the consequences of secondary and higher order harvest decisions for future production for each salmon stock under the jurisdiction of the management program.

As the life cycle progresses, a cycle of shorter period moves the salmon offshore, and then onshore, with the shorter cycle being repeated one or more times, depending on the species and life history type. As the cohort grows older, tertiary (Figure 2, box 2.10) and higher (boxes 2.12, 2.14, 2.16, 2.18) harvest decisions on the cohort are increasingly likely to result in landings and less likely to result in collateral mortality. For example, coastal troll (commercial hook and line) salmon fisheries target larger, older salmon with collateral mortality of salmon below the legal size limit being inversely proportional to size.

METHODS

The principles and criteria were initially assembled from a literature review and submitted to a process of review and comment within the State of Alaska in July, 1997. From then until January, 1998, the work passed through two scientific peer reviews by the University of Alaska Faculty of Fisheries and the Alaska Department of Fish and Game, and public review by panel composed of representative of fisheries interests. During public meetings convened by the states' fisheries public involvement and regulatory body, the Alaska Board of Fisheries (the Board), comments from the general public were also provided.

Following the public and peer review process, an expert panel was assembled from among scientists of the Alaska Department of Fish and Game to assist the author on revision of the work. The principles and criteria produced by the expert consultation were edited, reorganized and presented here.

Although there are many supporting references cited elsewhere, all of the principles and most of the criteria were adapted from seven primary source areas (Eggers 1993; FAO 1995; Olver, Shuter et al. 1995; Starnes, Jiminez et al. 1995; Mangel, Talbot et al. 1996; MSC 1996; NRC 1996). Relevant principles and criteria from these works are reproduced in the Appendix (Tables A - 2 through A - 9 and Table A - 12). The broad common themes among these sources made their adaptation for the present purposes relatively straightforward. First of all, the Alaska Department of Fish and Game has developed and applied principles and criteria for the sustainable management of salmon fisheries resources (Table A - 9), and some of these have been published in peer reviewed scientific literature (Eggers 1993; Baker, Wertheimer et al. 1996; Holmes and Burkett 1996).

Supporting sources two through four are the published results of three expert consultations. As source two, a set of principles for the conservation of wild living resources (Table A - 2) was developed by a committee of forty-two internationally recognized scientific experts on management of renewable resources of all kinds (Mangel, Talbot et al. 1996). Among the members of the Mangel committee were several leading experts in the management of fisheries, including Pacific salmon fisheries. Source three, the Code of Conduct for Responsible Fisheries, the Code, also resulted from an international peer review process that involved many of the world's leading fisheries experts over a period of more than four years (FAO 1995). The Code contains principles and standards for conservation, management and development of fisheries, including harvest management, fishing operations, and fisheries research

(Tables A - 5 and A - 6). In the fourth source, the expert panel was focused on salmon problems in the contiguous United States, but also included aspects of the problems in Canada and Alaska (Table A - 12). The Committee on Protection and Management of Pacific Northwest Anadromous Salmonids was composed of fifteen experts representing a very broad range of expertise in genetics, fish ecology, fish biology, inland waters and ocean science, anthropology, social science, political science, international fisheries and transboundary issues, habitat and habitat rehabilitation, hydrology, hatcheries, dams, fishery management and fishery science (NRC 1996).

The fifth primary source for supporting principles (Table A - 8) was the general principles of the draft North American Fisheries Policy, authored by a panel of experts selected by the publisher, the American Fisheries Society (Starnes, Jiminez et al. 1995). The sixth primary source was a thought provoking and challenging set of general fisheries conservation principles (Table A - 7) by Olver et al. (Olver, Shuter et al. 1995). The work of Olver et al. (1995) is included because it was published for the express purposes of supporting and stimulating research into the scientific basis for conservation management practices, which is also an objective of this work. The seventh primary source, although not published, is the draft principles and criteria on sustainable fishery management (Tables A - 3 and A - 4) of the Marine Stewardship Council, MSC, (MSC 1996). Even though the MSC principles and criteria are not the result of a scientific peer review process resulting in publication, they are presented here as the result of an expert consultation focused solely on fisheries that included a number of the same fisheries scientists who were part of the Mangel committee (Mangel, Talbot et al. 1996) and the consultations that led to the Code (FAO 1995).

In addition to the seven primary sources cited above, there are two processes for building principles and criteria of sustainable salmon management that are noteworthy. The Washington Fish and Wildlife Commission, WFWC, is in the process of developing and adopting a joint tribal-state wild salmonid policy. The joint policy process seeks to establish principles and criteria on spawning escapements, genetic diversity, ecological interactions, harvest management, hatcheries, and habitat protection and restoration (WFWC 1997). In addition to the WFWC process, there is a regional process for addressing sustainable management of fisheries, the Sustainable Fisheries Foundation (Bothell, Washington). At two conferences in 1996, one in Victoria, British Columbia, and the other in Seattle, Washington, the Foundation has fostered development of a set of draft principles for sustainable fisheries management that include harvest management, protecting and restoring habitats, community involvement, production strategies, and effective institutional and regulatory structures (Applegate, Bisson et al. 1996).

Definition of Terms

A principle is defined as a rule or standard, especially of good behavior. A criterion is a test on which a judgement about the degree of correspondence of any given situation to the standard can be made. Each of the five principles, or standards, for sustainable salmon fishing (Table 1) is accompanied by a collection of tests called criteria (Table A - 1) that can be applied to determine the extent to which the principle is applied in practice. The principles are described in relation to the salmon fishery models. The scientific bases for each of the principles and criteria are documented in the Discussion. For the sake of reference, a single table of the principles and criteria is included in the Appendix, along with definitions of key terms.

RESULTS

Principles and Criteria for the Sustainable Management of Salmon

Principle I. Protect wild salmon and their habitats

Protection of the native salmon populations and their habitats is the fundamental principle of sustainable salmon management. The central test of sustainable salmon management is the degree to which spawning, rearing, and migratory habitats are protected (Table A - 1, I. 1). A key test of the extent of protection is that salmon stocks and their habitats are not perturbed beyond natural boundaries of variation Table A -1, I. 1. A).

Prevention of loss and restoration are integral functions that accompany human activities that alter salmon habitats. In the case of proposed salmon habitat alterations, an essential test is the existence, and extent, of a process for scientific assessment of possible adverse ecological effects of habitat alteration that occurs prior to approval of the proposed alteration of salmon habitat (Table A - 1, I. 1. B). Where habitat alterations have already occurred, the quality of sustainable salmon management depends on the degree to which adverse environmental impacts on wild salmon and their habitats are assessed and corrected (Table A - 1, I. 1 .C). Prevention of loss and restoration require identification and protection of all essential salmon habitats in marine, estuarine and freshwater ecosystems (Table A - 1, I. 1. D). These “critical habitats” include areas in freshwater such as spawning beds, freshwater rearing and adjacent riparian zones, estuarine and near-shore marine rearing areas and adjacent coastal zones, and offshore marine rearing areas (Table A - 1, I. 1. D, i. - v.). Integration and coordination of protection for habitat are required for interdependent components of the watersheds (Table A - 1, I. 1. E).

Protection of salmon is a management process that occurs throughout the life cycle. In a sustainable salmon fishing program, provisions are made to protect salmon within spawning, rearing, and migratory habitats (Table A - 1, I. 2). It is particularly important that losses of salmon resulting from habitat loss (collateral mortality) be understood and communicated to the affected user groups (Table A - 1, I. 3), along with the more routine information regarding catches and escapements.

Principle II. Maintain escapements

Routinely seeding the spawning grounds at levels appropriate to the long term well being of the populations and interdependent species is a core axiom of sustainable salmon fishing. The test of the how the axiom is being applied is the extent to which the temporal and geographic magnitudes of spawning escapements are being measured (Table A - 1, II. 1). The existence of a standard to judge success in seeding the spawning grounds, the escapement goal, is also a key test of sustainable salmon fisheries management. In sustainable salmon fishing, escapement goals are established in a manner consistent with sustained yield (Table A - 1, II. 2).

Beyond having, measuring and attaining escapement goals, the quality of the escapement assessment programs provide essential tests of sustainable salmon management programs. Escapement goals are range limits, low and high, of the number of spawners appropriate to a drainage. In a sustainable management program escapement goal ranges incorporate the uncertainty associated with measurement techniques, observed variability in the population measured, and the varying abundance within related sub-stocks of the population measured (Table A - 1, II. 3).

Another important quality of the escapement is its geographic distribution within the spawning drainages and across populations within the drainage. As a rule, escapement goals are achieved in a manner consistent with appropriate geographic and temporal distribution of spawners (Table A - 1, II. 4). Achieving specified levels of escapement and controlling the distribution of escapements among populations within the watersheds requires sources and locations of fishing mortality to be understood (Table A - 1, II. 5). Understanding sources and locations of fishing mortality is an important factor in controlling mortality of species or life history types other than those targeted by the fishery (collateral mortality). Consequently, it is important to sustainable fishing that escapements be achieved in a manner consistent with protection of non-target stocks or species (Table A - 1, II. 6).

Understanding why attaining escapement goals is effective at providing sustainable fishing requires understanding the biological characteristics of the escapements and their role in the ecosystem. How the different components of the escapement are adapted to the watershed is understood by examining the physical, or phenotypic, characteristics of escapement (Table A - 1, II. 7). The origin and evolutionary histories of the different components of the escapement, as understood through the genetic characteristics of the escapement (Table A - 1, II. 7), provide essential insights into how to apportion the escapement among populations within the watershed (Table A - 1, II. 4).

Part of the reason that escapement goals are effective in sustaining salmon fishing is their contribution to normal ecosystem function. Understanding the contributions of the escapements to sustaining other species and processes in the ecosystem provides guidance on appropriate levels of escapement within the watershed (Table A - 1, II. 8). A key test of normal ecosystem functioning is made by examining the population trends of the salmon and allied species (Table A - 1, II. 9).

Principle III. Harvest with caution

Knowledge of the status and biology of both salmon and habitat, determine how much of the total resource should be harvested. A primary test of consistency between the levels of knowledge and harvest is the extent to which a precautionary approach is applied to the regulation of activities that alter essential habitat, as well as to harvest and other consumptive uses of salmon (Table A - 1, III. 1 and III. 2). Habitat degradation results in salmon harvest. Habitat and harvest managers share a common purpose in harvest control. A further test of the consistency of harvest practices with this principle is the degree to which conservation and management decisions for fisheries take into account the best available information, including environmental, economic, social, and resource use factors (Table A - 1, III. 3). In this regard, the best available scientific information on the status of populations and the condition of their habitats is expected to be routinely updated and peer reviewed (Table A - 1, III. 4). When deficiencies in scientific information are identified, upholding this principle requires that data collections and research are undertaken in order to improve scientific and technical knowledge of fisheries including their interactions with the ecosystem (Table A - 1, III. 5). How to correct deficiencies in knowledge with respect to new fisheries is expected to be addressed by proposals to fish for unexploited populations, or to introduce a new gear type. In the context of sustainable salmon fishing, proposals for salmon fisheries development or expansion are expected to document resource assessments and other applicable criteria required for sustainable management (Table A - 1, III. 6).

Principle IV. Maintain effective management system

The ability to manage human uses of salmon and their habitats is a prerequisite for sustainable salmon fishing. It is important that the regulatory institutions be as extensive and detailed as the fisheries being managed. A cardinal test of management capabilities is the extent to which salmon management objectives appropriate to the scale and intensity of use are in place (Table A - 1, IV. 1). Given that policy objectives, stock status and the nature of fishing effort are continually changing, an effective sustainable salmon management program needs to incorporate the means for periodic evaluation. A test of the effective management system is the extent to which the management objectives are subject to periodic review (Table A - 1, IV. 2). For ready evaluation, the management objectives are expected to be published in the forms of harvest management plans, harvest management strategies, guiding principles, and policies for managing mixed stocks, fish disease, and genetics (Table A - 1, IV. 2).

Effective sustainable salmon management also requires periodic evaluation of statutes intended to sustain productivity of salmon habitats. One test of the effectiveness of habitat protection laws and regulations is the extent to which they are regularly evaluated and documented (Table A - 1, IV. 3).

Further facilitating evaluation of the management system, government is expected to have an open process for objectively evaluating the effectiveness of fishery management actions (Table A - 1, IV. 4). Such a process needs to explicitly provide management with the means to separate biological and allocation issues (Table A - 1, IV. 5).

More detailed mechanisms of evaluation provide additional tests of the sustainable salmon fishing management system. Feedback loops are expected to be consistently applied to elements in the management process, using post-season management action indicators (escapement habitat maintenance within current regulations, etc.), to verify that the management actions actually sustained salmon populations, fisheries and habitat. Where deficiencies are documented, actions are taken to resolve them (Table A - 1, IV. 6). Evaluation is expected to occur at each level of the sustainable fishery management system. Fisheries management implementation and outcomes are expected to be consistent with Board of Fisheries regulations, and Board regulations are expected to be consistent with Alaska statutes (Table A - 1, IV. 7).

Timely implementation and enforcement of management objectives is a hallmark of sustainable salmon management. Management is expected to act in a timely and adaptive fashion to implement objectives on the basis of the best available scientific information (Table A - 1, IV. 8). Timely management actions require statutory and regulatory authority. A management agency capable of implementing sustainable salmon fishing has clear authority (in statute and regulation) to control human-induced sources of salmon mortality, including mortality due to habitat loss, a form of collateral mortality (Table A - 1, IV. 9). In addition to habitat degradation and loss, the sustainable salmon management system is cognizant of all other established, and potentially important sources of collateral mortality. In this regard, management takes into account the consequences of artificial propagation of salmon on natural stocks (Table A - 1, IV. 10).

The effective sustainable salmon management agency also needs to be able to deliver compliance with fishing and habitat management regulations. Consequently a central test of an effective management system is the degree to which management incorporates appropriate procedures for effective compliance, monitoring, control, surveillance and enforcement (Table A - 1, IV. 11).

Effective salmon management transcends political boundaries. The effectiveness of salmon management is appraised by the extent to which management recognizes the transboundary nature of aquatic ecosystems by encouraging multilateral cooperation in research and management (Table A - 1, IV. 12). For transboundary stocks appropriate procedures for effective compliance, monitoring, control, and surveillance are coordinated with those of other states (countries) or agencies (Table A - 1, IV. 13). Transboundary compliance monitoring and enforcement implies that effective joint assessment and management arrangements are in place for stocks that cross jurisdictional boundaries (Table A - 1, IV. 14).

Implicit in delivering compliance and all other responsibilities, is the test of the extent to which management has access to the resources necessary for collection and dissemination of the information and data necessary to carry out management activities (Table A - 1, IV. 15). The test of adequate resources explicitly evaluates the degree to which government provides adequate staff and budget for the research, management and enforcement activities necessary to implement the sustainable fisheries management principles (Table A - 1, IV. 16).

Principle V. Maintain public support and involvement

In addition to suitable habitat, spawning escapements, and effective management, the active involvement of a broad cross section of the public is essential to sustainable salmon fishing. The cardinal test of the health of the public contribution toward sustaining salmon fishing is the presence of a governmental process that incorporates appropriate mechanisms for resolution of disputes (Table A - 1, V. 1). The mechanisms are expected to include an open and fair public involvement process that addresses management and harvest allocation decisions (Table A - 1, V. 2) and an allocation of the conservation burden for salmon across all consumptive user groups (Table A - 1, V. 3). An additional test of the adequacy of the governmental process to support sustainable salmon fishing is the extent to which it provides adequately funded public information and education programs for the public (Table A - 1, V. 4). The public needs to be informed concerning salmon habitat requirements, salmon habitat threats, the value of salmon and habitat to the public and the ecosystem, natural variability and population dynamics, the value of salmon to other fish and wildlife, current status of Alaska fish stocks and fisheries, and the Alaska Board of Fisheries process (Table A - 1, V. 4).

The degree to which management contributes to the success of the public involvement process provides two key additional tests of the public involvement process. Within the process, effective management provides for dissemination of results of management actions and monitoring to all interested parties in a timely fashion (Table A - 1, V. 5). In this context, management is expected to promote public understanding of the proportion of mortality inflicted on each stock by each consumptive user group (Table A - 1, V. 6).

The Sustainable Salmon Fishery

As an ideal, a sustainably managed salmon fishery is one in which the agents of an effective management system (Principle IV) use information on the status of the wild salmon and its habitats throughout its life cycle to make a series of risk-averse management decisions (Principle III; Figure 1, boxes 1.4 and 1.9) that deliver escapements sufficient (Principle II) to maintain short-term and long-term resource productivity (Principle I; Figure 1, boxes 1.4 and 1.9). The harvest decisions are consistent with guidelines developed in a public involvement process (Principle V). As part of protecting the short-term productivity of salmon, managers harvest the salmon stocks in a manner consistent with the degree of uncertainty regarding the status of the biology and the resource (Principle III; Figure 1, box 1.6). Catch accounting is used to promptly put into action regulations that respond to short-term fluctuations in production of the species and stocks that are harvested (Criteria III. 4 and IV. 8; Table A - 1). Catch data provide information relevant to stock structure and other attributes appropriate to protection of genetic diversity (supporting Criteria II. 1 to II. 7, Table A - 1). Spawning escapements are provided within ranges necessary to conserve and protect potential salmon production and to maintain normal ecosystem functioning (Principle II, Figure 1, box 1.5). A knowledge of the status of critical spawning and rearing habitats, as they influence productivities of the species and stocks in the fishery, is fed forward through habitat management decisions (Principle I, Figure 1, box 1.9).

The extent to which a management entity has been able to establish and apply an effective management system to control human activities that affect salmon (Principle IV) is evaluated by the contents of all the decision boxes in the Extended Salmon Fishery (Figure 2). Note that the harvest management process may be repeated in all habitat types, freshwater (boxes 2.2 - 2.5), onshore (i.e. boxes 2.6 - 2.9) and offshore (i.e. boxes 2.14 - 2.17), on all life cycle stages, and in multiple management jurisdictions. It is often the case that the non-target landings of one fishery is the target stock of another fishery. It is the serial nature of salmon harvests in time that makes coordination and cooperation among salmon managers in all geographic localities an important component of sustainable salmon management. The extent to which the management entity under review understands the components of Figure 2 with respect to the stocks it manages is critical to meeting the criteria described under Principle III (Table A - 1).

One goal for sustainable salmon management is to decrease the degree of uncertainty regarding the status and biology of the resource (Principle III) by developing the catch and escapement information to inform production estimation. Each harvest cycle (Figure 2, boxes 2.2 - 2.5, 2.6 - 2.9, ... , 2.18 - 2.1) contributes information (Figure 2, boxes 2.3, 2.4, 2.7, 2.8, 2.11, 2.12, 2.15, 2.16, 2.19, 2.20) to the salmon fishery management program that is responsible for estimating the production of the cohort. Such production information from the management entity in the originating watershed (Figure 2, boxes 2.1, 2.5, 2.9, 2.14, 2.17) is used to build sustainable salmon fishery harvest decisions (Figure 2, boxes 2.2, 2.6, 2.10, 2.14).

Policy Roles in Sustainable Salmon Management

Public policy plays a dominant role in sustainable salmon management. Clear distinction needs to be made between policy and science in order for sustainable salmon management to be effectively implemented. Indeed, implementation of a sustainable salmon management program is a policy decision that has been made at the level of the Alaska State Constitution, and at the federal level in the Magnuson-Stevens Fishery Conservation and Management Act, and the Endangered Species Act. Policy has a role to play in each of the elements of the Salmon Fishery, and some additional roles are added by the structure of the Extended Salmon Fishery.

The basic role of public policy in the implementation of sustainable salmon fishing practices is to reconcile theory to application, by keeping a clear vision of the present differences between what is currently possible, and what may remain to be accomplished in order to fish sustainably. As the complexity of the demands on salmon resources increase in relation to human population size, so do the information demands on salmon harvest managers. For each use to which humans put the salmon, there is a price to be paid for the information necessary to manage that use in a sustainable fashion. It is up to the policy process to see that the price paid and the terms of payment are affordable for those who depend on the salmon resources for a living.

Unfortunately, it has often been the case that managers need to know more about the status of the salmon resources than the budgets provided by society permit them to learn. The role of policy, therefore, is to set the scope of sustainable salmon management by seeking to focus budgets on answering the questions necessary to implement sustainable management in each fishery, and to keep pressing managers for less expensive answers to those questions. The growth of technology has made possible solutions to fisheries management information problems that were intractable only a few years ago, however these technologies may not be available within management agencies. Data acquisition technologies applicable to salmon biology are becoming less expensive, even as they require more specialized training to implement.

The role of public policy is to set the rules and fishery management plan objectives that establish the expectations for the performance of the harvest control system. Principles for the conservation of salmon fisheries resources need to be set in regulations as objectives for implementation. Periodic evaluation of the degree to which each salmon harvest management program has attained its objectives is necessary to guide the development of public policy for sustainable salmon fisheries management.

Setting Limits on Harvest Decisions

The role of public policy is to constrain the harvest decision (Figure 1, 1.4, 1.9 and Figure 2, 2.2, 2.6, 2.10, 2.14, 2.18, 2.23) by setting the objectives for each management entity. In establishing the performance criteria for conservation of salmon, in providing for the needs of subsistence harvesters, in seeking to maximize the long-term commercial landed value, in providing recreational fishing opportunities, and in providing for timber harvesters and land developers, policy is establishing objectives for the salmon management program. Harvest decisions are driven by the sum of the policy objectives for all of the salmon stocks and species that are caught or otherwise taken as a consequence of the harvest decision.

In establishing objectives for the stocks in the originating watershed, policy is also establishing constraints that limit the objectives of all the other salmon harvest cycles in which the stock of the originating watershed may be harvested. If management objectives in the originating watershed are not recognized and treated as constraints by other harvesting entities, the objectives for management in the originating watershed are moot. Harvest objectives of one harvest decision entity can compete with those of another. Allocation of the benefits and burdens of conservation among the entities making harvest decisions are two of the most difficult challenges for fisheries policy.

Attention of policy makers is often focused on allocation of the benefits of conservation to users groups, but allocation of the burden of conservation across all user groups, including habitat degrading users, is equally important from a scientific perspective. In the history of salmon fishing, allocation of the conservation burden has often been neglected, with the result being extremely limited options for those making the final (Figure 2, 2.18) harvest decision closest to the spawning grounds. When impacts of humans that degrade salmon habitats are not understood and accounted as unintentional fishing mortalities, it may be impossible to achieve escapement objectives, even when all intentional fishing has been eliminated.

Sustainable salmon management principles do not presume to prescribe how the burden of conservation is to be distributed. Sustainable management principles point out that all significant sources of mortality need an accounting. The decision on allocation of the conservation burden is made either consciously or unconsciously regardless of human wishes, and the requirement under sustainable management is that a conscious allocation of the conservation burden be made. In the absence of conscious allocation of the conservation burden across all user groups, policy makers have entered into a default decision to allocate the full burden of conservation to those fishing within, or near to, the originating watershed. The lack of a conscious decision also incurs a risk that conservation efforts will fail.

Management of Weak Stocks

The decision about which salmon stocks are too “weak” to protect is a policy call bearing the most serious potential consequences for salmon harvesters. The important question of whether or not to close a fishery to protect a so-called “weak stock” that is harvested in the midst of very numerous “strong stocks” is a policy question that examination of the Extended Salmon Fishery model (Figure 2) can help answer. The question of weak stock protection needs to be asked in the context of the cumulative impact of harvest on the future production of (each cohort of) each salmon stock. Policy makers cannot approach the question of weak stock protection from the context of the relative magnitudes of weak and strong stocks, but only from some qualitative or quantitative knowledge of how big a bite each fishery takes out of the weak stock's apple, and the cumulative impact of all the bites from the apple. The problem faced by migratory fish species in general is that a great many fisheries take relatively small portions of a stock without any concept of how much of the apple is left (Garcia 1994).

Thus, protection of "weak" stocks is a critically important policy issue, because it is a decision about the allocation of both the harvest of, and the conservation burden for, a salmon stock among a series of fisheries (see Figure 2). Without the types of information illustrated by the Extended Salmon Fishery, policy makers cannot render an informed decision about such an allocation. In the absence of an informed allocation decision, very severe and precipitous consequences can befall the fisheries involved, as has been experienced in the southeastern Alaska troll fishery for chinook salmon during the past several years. If the burden of conservation for a salmon stock is not consciously apportioned by the policy process across the chain of localities symbolized in the Extended Salmon Fishery, then the bulk of the burden of conservation can fall on the weakest political link in the chain when a stock fails and a higher law, such as the Endangered Species Act, is applied to the management of the fishery.

Catch and Escapement Programs

The role of policy in escapement and catch (Figure 1; 1.5 and 1.6; Figure 2; 2.3, 2.7, 2.11, 2.15, 2.19 and 2.4, 2.8, 2.12, 2.16, 2.20) is to see that information sufficient to support established objectives is being collected. Periodic independent evaluation of the management program provides policy makers with the ability to exercise policy oversight.

Salmon Production Estimation

Policy plays an important role in the salmon production estimation element (Figure 1; 1.1, 1.2, 1.3; Figure 2; 2.1, 2.5, 2.9, 2.13, 2.17). In establishing the objectives for the fishery, the policy body has also prescribed the nature of the methods used to estimate salmon production. Setting the policy objective of maximizing the long-term catch for a single stock of a salmon species without constraints providing for limits on bycatch or protection of the ecosystem sets in motion a certain type of information gathering program that produces a type of production estimate suitable to that objective. Altering the policy objective to maximize the catch from a mixture of stocks of a single species requires another set of information gathering programs and estimation procedures. Adding constraints on non-target landings, or imposing limitations on incidental catch, to the policy objective prescribes still other information gathering pathways and production estimation procedures. Although each type of production estimation procedure can have many of its information requirements in common with other similar procedures, each time the policy objective for the salmon management program is altered, the production estimation procedure and its information requirements necessarily change.

As consequences of the variety of scientific approaches available to set escapement goals and the differences in stock structure of salmon in different localities, the method used to set the goal is not solely a matter of science, but also one of policy. As is the case for all the basic elements of the Salmon Fishery model (Figure 1), the type of policy question asked determines the type of scientific answer tendered. The choice of scientific approach depends on the objectives of the management program that are set by the policy makers, as well as on the availability of data. For example when there is a long time series of age-structured escapement data for a salmon stock, and the objective set by the public policy process is to maximize long-term harvest of single stocks, the approaches to setting escapement goals that were analyzed and discussed by Eggers (1993) are indicated.

When sufficient stock-specific catch and escapement data necessary for the approach used by Eggers (1993) are lacking, or when there are strong interactions between broodyears, or when there are other management objectives set by policy makers, habitat capacity might be used to set escapement goals. For example, policy makers may wish to quantify the salmon resource in terms of its freshwater habitat in order to better resist habitat degrading activities in other sectors of the policy arena. Providing information to help policy makers as they struggle to balance salmon production against other competing uses of the watershed such as timber and mineral extraction, housing development and associated road building may require habitat-based production estimates (Walters 1996b).

Coordination and Implementation

In addition to the role of policy in the four elements of the harvest cycle in the Salmon Fishery model (Figure 1, 1.3 - 1.6), there are other policy roles indicated by the additional corresponding elements of the Extended Salmon Fishery model. Among the primary responsibilities of policy makers in implementing sustainable management in the Extended Salmon Fishery are coordination among the entities making harvest decisions on the cohort, exchange of information on production, catch and escapement as may be required by each the management objectives of each management entity (see Table A - 5, 6.10). Resolution of policy disputes over the allocation of landings and the burden of conservation among the entities is required in order for sustainable salmon fishing to proceed.

DISCUSSION

Principle I. Protect wild salmon and their habitats

The goal of conservation for sustainable use is to secure present and future options by maintaining biological diversity at genetic, species, population and ecosystem levels; as a general rule neither the managed resource nor any other components of the ecosystem should be perturbed beyond natural boundaries of variation (FAO, 1995; Table A - 5; 6.1 , 6.2, 6.3, 6.8, 6.10; Olver et al., 1995, Table A - 7; 1 , 2 and 5; Starnes et al., 1995; Table A - 8; 1, 6, and 7; MSC, 1996, Table A - 3; 2; Mangel et al., 1996; Table A - 2; II). The point of sustainable salmon management activities is to keep the full range of salmon resources productive to the full extent possible (Paulik, Hourston et al. 1967). Protection of salmon production in the short-term takes the form of limiting harvests to allow adults to reach the spawning grounds (Mundy 1985). Protecting the salmon production in the long-term means protecting the spawning and rearing habitats, including the entire salmon bearing ecosystem, from degradation (Nehlsen, Williams et al. 1991; Huntington, Nehlsen et al. 1996; Myers, Kope et al. 1998) . Habitat protection takes the form of land use planning and regulation, including regulating natural resource extraction activities.

In Alaska, as elsewhere, protection of spawning and rearing habitat is likely to be as important to long-term sustainable salmon production as harvest control is to short-term sustainable salmon production (Walters 1996b). Some of the best known Alaskan salmon populations have survived decades of apparent overharvest (Cooley 1963) to prosper under escapement goal management (Mundy 1996). It is probable that an important factor enabling these Alaskan salmon populations to rebound from the effects of a prolonged period of uncontrolled harvest was the health of their spawning and rearing habitats (Mundy 1996). On the other hand, experience from the Pacific Northwest has demonstrated that salmon populations are unlikely to recover from habitat degradation and loss even with total closures to fish harvest (Kostow 1996; Mills, McEwan et al. 1996).

The integration of traditional salmon harvest management with habitat monitoring and protection is essential to the sustainable use of Alaska's salmon resources. While harvest managers are adept at dealing with the transient shocks of fishing mortalities, they do not readily incorporate the chronic effects of natural and man-made habitat alterations into production estimation and escapement goal evaluation. Habitat data are often collected in divisions of the agency other than those in which the harvest managers work, or in other agencies altogether. The separation of harvest management from habitat monitoring may create an “institutional blindness” that makes managers slow to react to chronic changes in habitat productivities.

Loss and corruption of the freshwater habitats of salmon and steelhead is a common theme in the decline of both anadromous and resident salmonids in the contiguous northwestern United States (Henjum, Karr et al. 1994). It is important to manage entire watersheds as dynamic units (Bisson, Reeves et al. 1996), and to ensure that water quality is fully protected in order to sustain fish production. A full description of the various sources of risk to freshwater, estuarine, and nearshore and offshore marine habitats is essential to fishery management. Protecting the productivity of all of these elements of salmon habitat is essential in order to sustain the production of salmon for the commercial, sport and subsistence fisheries throughout Alaska. A thorough description of the current risks to salmon habitat in Alaska is beyond the scope of the this work. An outline of the risks includes the geographic extent of logging, loss of wetland hydrological functions, chronic sediment input from roads, blockages to fish passage in streams, loss of natural streambanks, water quality degradation, human-accelerated erosion of steep hillsides and stream banks, loss of riparian and wetland habitat from commercial and residential development, and general urbanization.

I. 1. Protections for salmon habitat

In a preliminary analysis, the extent of protection of salmon habitat may be determined from statutory provisions. For example, the federal 1996 Magnuson-Stevens Fishery Conservation and Management Act (Sustainable Fisheries Act, SFA) recognizes the decline in the quantity and quality of marine, estuarine and riparian habitats as one of the greatest long-term threats to the viability of sustainable fisheries. The definition of essential fish habitat under SFA is, "waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." The term "waters" is defined to include aquatic areas and their associated physical, chemical, and biological properties that are used by fish, and may include areas historically used by fish, and the term, "necessary" refers to the habitat required to support a sustainable fishery and a healthy ecosystem.

The Alaska Department of Fish and Game has the mandate under Alaska statute (AS 16-05.020) to " … manage, protect, maintain, improve, and extend the fish, game and aquatic plant resources of the state in the interest of the economy and the general well-being of the state." ADF&G is expected to play a leading role in identifying and mapping essential salmon habitat, as well as identification of activities that may adversely effect it. Protection of anadromous water bodies' water and substrate is affected by what goes on in both the riparian zone and the watershed, which requires that protection of salmon habitat needs to regulate activities beyond the stream bank (Beschta 1996).

Statutory protection is only an initial evaluator of habitat protection, since statutes vary in efficacy. For example, the federal Endangered Species Act, ESA, requires critical habitat for the listed species to be designated at the time of the listing to the “maximum extent prudent and determinable” (Section 4(a)(3)). The actual efficacy of this habitat protection appears to be low, since only sixteen percent of listed species had critical habitat designated in regulations as of 1992 (Clark 1994).

Beyond the review of statutes, more in-depth analysis of habitat protections requires an evaluation of the status of detailed habitat protection criteria (Table A - 11). Developing a better understanding of the basic watershed processes that support salmon production for each fishery is essential to increase the ability to provide detailed habitat protection criteria in the future (Bisson, Reeves et al. 1996).

The current knowledge regarding forestry impacts to fish habitat suggest the need to improve fish habitat protection under the State of Alaska Forest Resources and Practices Act to ensure sustainable fisheries (ADF&G, Habitat Division, personal communication). In Alaska, habitat management decisions need to be evaluated in the fields of forestry; agriculture; mining; residential, commercial and urban development in riparian zones, wetlands and tidelands; and hydroelectric power development. Also to be evaluated are habitat decisions concerning reduction of instream flows to serve community water supplies and other water export developments (Alaska Department of Fish and Game, Habitat Division).

I. 1. A. Perturbation within normal limits of variation

As a rule of thumb, salmon populations and habitats lie outside the limits of normal variation when they exhibit linear trends in population abundance or productive capacity for more than two generations. Sustained time trends in salmon populations or in habitat capacities require responses from managers in order to sustain salmon production (Walters 1986; Walters and Parma 1996). Negative time trends in abundance in combination with increasing trends in serious human perturbations of critical habitat are indicative of unsustainable salmon populations (Nehlsen, Williams et al. 1991; Huntington, Nehlsen et al. 1996; Lichatowich 1996). Sustainable salmon management is recognized by the degree to which human perturbations of salmon and habitats beyond normal limits of variation are avoided. Serious human perturbations are actions that have the potential to render salmon stocks and their habitats permanently unsuitable or dysfunctional. Certain types of dredging of stream bed materials and permanent dam building are examples of serious human perturbations. Obviously, perfect compliance with this criterion would rarely be found outside of areas where nearly all economic enterprises are prohibited such as parks, refuges, sanctuaries, and designated critical habitats.

A key concern in managing stocks and habitats within normal boundaries of variation is sufficient scientific data. The concept of "normal variation" implies information is available to conclusively document what the natural boundaries of variation are. Further, knowing the contributions of components of the ecosystem to normal variation is even more challenging. For example, information is lacking to predict the percent loss in salmon production from a stream with increased turbidity as a result of mining. Although such incremental effects of degradation on habitat and salmon are notoriously difficult to measure (Bisson, Reeves et al. 1996; Espinosa, Rhodes et al. 1997), the spirit of this criterion (I. 1. A) is to avoid permanent or long-term damage through major human actions, i.e. dam building, or cumulative impacts of minor human actions, i.e. riparian zone home building and development. Based on a very long history of experience with habitats and salmon populations outside of Alaska (Netboy 1974; Netboy 1980), human activities that constitute threats to the normal boundaries of variation are readily identified, if not easily controlled.

I. 1. B. Assessment of adverse effects of habitat alteration

Without scientific assessment of possible adverse ecological effects of habitat alteration prior to approval of proposed alterations of salmon habitat, policy makers cannot make informed decisions about the true cost of the proposed activity (Ludwig, Hilborn et al. 1993). The elements of the assessments are detailed in the extensive literature on the role of habitat degradation in the extirpation of salmon. More than ninety percent of the documented extinctions or long-term declines of Pacific salmon have been associated with degradation of spawning and rearing habitats (Johnson, Flagg et al. 1991; Matthews and Waples 1991; Nehlsen, Williams et al. 1991; Waples, Johnson et al. 1991; Waples, Jones Jr. et al. 1991; Busby, Johnson et al. 1993; Busby, Wainright et al. 1994; Johnson, Waples et al. 1994; Waknitz, Matthews et al. 1995; Weitkamp, Wainright et al. 1995; Baker, Wertheimer et al. 1996; Bisson, Reeves et al. 1996; Bottom 1996; Busby, Wainright et al. 1996; Frissell, Liss et al. 1996; Gregory and Bisson 1996; Hard, Kope et al. 1996; Huntington, Nehlsen et al. 1996; Johnson, Lincoln et al. 1996; Kostow 1996; Lichatowich 1996; Mills, McEwan et al. 1996; Mundy 1996; Northcote and Atagi 1996; Slaney, Hyatt et al. 1996; Espinosa, Rhodes et al. 1997; Myers, Kope et al. 1998; Wentz, Bonn et al. 1998). In particular, losses of flood plain habitats in both montane and lowland riparian forests (Gregory and

Bisson 1996), and losses of lake rearing habitats (Fryer 1995) have been major contributors to salmon declines and extirpations in the contiguous United States.

Assessment of adverse effects of habitat alteration should encompass a full range of aquatic and riparian conditions on landscape scales large enough to encompass the life cycle of the salmon species (Bisson, Reeves et al. 1996; Gregory and Bisson 1996). A detailed set of criteria for protection of freshwater salmon habitats (Murphy 1995) has been published by the National Marine Fisheries Service (Table A - 11). The detailed criteria underscore the concept that protecting the interaction between terrestrial and aquatic systems by protecting the riparian zones from degradation is essential to production and diversity of salmon populations (Beschta 1996; Bisson, Reeves et al. 1996).

In addition to direct measures of habitat attributes, measurements of abundance and distribution of juvenile salmon (Walters 1996b), and the contribution of marine nutrients to the ecosystem (Bilby, Fransen et al. 1996) are essential for detection of adverse effects of habitat alteration. When only adult salmon abundance information is routinely collected, detection of adverse effects of habitat alteration on salmon populations is not possible. For commercially and recreationally harvested stocks, the effects of habitat degradation may be impossible to separate from the effects of harvest until enough time has passed for the habitat loss to become irreversible (Mundy 1996). The difficulties of detection of habitat degradation using only salmon abundance is also made difficult because several generations return from the ocean before the effects of freshwater habitat degradation appear as declines in recruitment (#5, Table A – 11). Marine influences contributing to natural run fluctuations (Francis and Hare 1994) may mask habitat damage for a decade or much longer (Finney 1998). Similarly losses of basic habitat productivity due to low salmon escapements (Mathisen 1972; Kline Jr., Goering et al. 1993; Piorkowski 1997) may be confused with the effects of fisheries interceptions or marine climate trends. Use of marine nitrogen in sediment cores from freshwater spawning and rearing areas to reconstruct pre-historical abundance of salmon offers some insights into how to separate the effects of climate from those of fishing (Finney 1998).

I. 1. C. Correction of adverse environmental impacts

Sustaining salmon in the long-term requires not only that adverse environmental impacts on wild salmon and their freshwater and marine habitats be assessed before degradation, if possible (Criterion 1. 1. B), but also that they be corrected when appropriate. Assessing the relation between the status of habitats and salmon production needs to be an integral part of salmon management programs. Habitat-based salmon production estimates are essential to allow fishery managers to factor habitat constraints into their allocation decisions. Habitat status information allows managers and policy makers to avoid continuing unsustainable harvest levels in the face of long-term declines in freshwater or marine productivities (Beamish and Bouillon 1993; Francis and Hare 1994; Bisson 1996).

Ongoing assessment of salmon habitat needs to advise habitat altering activities because correction of damaged and occluded habitats is an extraordinarily difficult challenge with no certain outcome (Beschta 1996). Once habitat has been degraded or occluded, and once salmon runs have sharply declined or disappeared, it may be difficult, or impossible to restore salmon production. The restoration of healthy salmon populations to Canada's Fraser River sockeye salmon habitats after the Hells Gate disaster took over fifty years of intensive scientific and political efforts, 1912 - 1968 (Roos 1991). In general, attempts to introduce salmon into barren habitat, and to re-introduce salmon into areas from which they have been extirpated have high failure rates, and it may require several generations of continuous stocking when they do succeed (Cuenco, Backman et al. 1993). Successfully introducing salmon into areas where they are not present is difficult, in part, because salmon profoundly change those ecosystems where they do occur toward states that support production of salmon (Mathisen 1972; Koenings and Burkett 1987; Bilby, Fransen et al. 1996; Koenings and Kyle 1997; Piorkowski 1997). The conclusion is that having good salmon habitat requires keeping salmon in the habitat.

I. 1. D. Essential habitats protected

Sustainable management of salmon is a "gravel to gravel" process whereby all essential salmon habitats in marine, estuarine and freshwater ecosystems are protected. The term "gravel to gravel" means that salmon habitats form a chain that starts and ends with the spawning gravels (Figure 1, box 1.5). When any link in the chain of habitats essential to support the salmons' life cycle is broken, the chain ceases to function and the salmon and their fisheries are lost. Historical accounts of the interaction between human and salmon populations demonstrate the necessity of the complete life cycle approach to sustainable management of salmon (Netboy 1974; Netboy 1980).

Among the different types of essential habitats, the most is known about the importance of healthy forests to sustainable salmon populations. The U.S. Forest Service has identified a wide variety of negative effects on essential fish habitat (Table A - 10) in Alaska's Tongass National Forest due to timber harvest and road building (USFS 1995). Although all activities associated with harvest contributed to degradation of essential fish habitat, the greatest risk was identified as road building. Disappointingly, application of the Best Management Practices, BMP's, was not found to be sufficient to insure protection of high quality fish habitat and long-term conservation of fish stocks. See also (Espinosa, Rhodes et al. 1997). Although seven recommendations were made to improve protection of essential fish habitat, only three of these were actually adopted into the new management plan for the Tongass (Table A - 10). A further detailed list of essential salmon habitats (Table A - 11) was provided by the National Marine Fisheries Service (Murphy 1995).

Basic works on the habitat requirements of salmonids define some of the types of habitats that are essential to protect and criteria for their protection (Salo and Cundy 1987; Chapman 1988; Bjornn and Reiser 1991; Beschta 1996). Federal forest plans incorporating techniques that may quantify factors important to habitat-based salmon escapement goal estimation have been developed (Murphy, Koski et al. 1990). Included in this work are models of habitat dependency for salmonids have been developed which describe freshwater salmon production as a function of habitat attributes (Murphy, Koski et al. 1990).

Habitat suitability and dependency measures are needed to evaluate the extent to which habitats are being protected because they offer fish habitat scientists and salmon harvest managers a common language. Among the many measures of habitat dependency and suitability that might be useful in Alaska, a few are most notable. The IFIM methodology has been applied to understanding changes in salmonid production as a function of habitat alteration following water withdrawals in the Trinity River, California (Bartholow, Laake et al. 1993). Conceptually related to IFIM is the weighted usable area, WUA, (Glova and Duncan 1985). The WUA defines the amount of usable habitat in a river for juvenile chinook salmon, adult chinook salmon, and other life cycle stages of other fish species, based on association between fish and average water velocities, depths, and substrate size, expressed as habitat suitability curves. Changes in the WUA as a function of water discharge (m^3/s) and the closely related variable, river channel width (m), can be used to illustrate the importance of discharge to different life cycle stages of chinook in maintaining diversity in channel form and flow (Ward and Stanford 1995).

There are four related habitat dependency measures that may help habitat scientists and harvest managers communicate. The Habitat Suitability Index, HSI, has been used to provide habitat-fish production estimation methodology for non-salmonid species (Pajak and Neves 1987). The HSI is very similar in concept to habitat dependency methodologies called Ecosystem Diagnosis and Treatment, EDT (Lestelle, Mobrand et al. 1996), and the Patient-Template Analysis, PTA, (Lichatowich, Mobrand et al. 1995) that have been developed for salmon in the

Columbia River basin. The PTA, EDT and HSI are similar in that they link attributes of the aquatic organisms of interest to the productive capacities of a series of critical habitats, called life history trajectories in EDT (Lestelle, Mobrand et al. 1996). A final example of a habitat dependency measure, the index of biotic integrity, IBI, is designed to evaluate the state of an aquatic resource based on the attributes of the indigenous fish communities (Karr 1981). Three categories of fish community attributes in IBI are the species composition, trophic composition, and health and abundance of fish.

I. 1. E. Watershed scale habitat protection

The scale of salmon habitat protection in freshwater must incorporate the entire set of connected components; uplands and wetlands; riparian zones and stream beds. The concept of landscape-scale salmon habitat protection is known as watershed management (Henjum, Karr et al. 1994; Murphy 1995; Bisson, Reeves et al. 1996). Fish habitat management in freshwater has undergone a transition in this century from stream barrier removal to landscape-scale application of the principles of adaptive management (Sedell, Reeves et al. 1996). The extent to which the different components of the habitat are integrated into a comprehensive watershed management program is the test of this criterion.

Watershed analysis is the process of measuring present condition of streams in terms of biophysical watershed processes and aquatic resource values, and the vulnerability of these processes and values to disruption by forestry (Bisson, Reeves et al. 1996). The watershed analysis process is important to sustainable salmon management because it allows the incorporation of habitat disturbance patterns into landscape planning, as recommended by both Bisson et al. (1996) and the National Research Council (1996). The types of measures of present conditions of the watershed that should be available to managers are the spatial context of the watershed, the temporal context and natural disturbance history, the range of riparian vegetation and availability of reference sites, and the history of human impacts (NRC 1996).

I. 2. Protection throughout the life cycle

Harvest management programs for adult salmon are but one part of successful sustainable salmon management programs (Walters 1996b). In addition to protection of spawning escapements, sustainable salmon management requires protection of salmon throughout the life cycle within spawning, rearing, and migratory habitats. Sustainable salmon management requires an effective network of small-scale institutions, land owners and water users that is well integrated into large-scale governmental institutions at all levels (Lee 1996b).

I. 3. Communicate losses of salmon due to habitat degradation

Collateral mortality resulting from habitat loss is understood and communicated to affected user groups. Protection of salmon within freshwater habitats requires identifying, documenting and communicating the losses of salmon due to habitat degradation to the affected members of the public.

Principle II. Maintain escapements

The concept of the escapement goal is fundamental to the practice of successful salmon fishery management (Mundy 1982; Eggers 1993; NRC 1996; Walters 1996b). The escapement goal is the annual number of adults, or a range of values, that the management entity intends to successfully spawn within a designated watershed. Having a recognized numerical objective for seeding of the salmon spawning grounds is fundamental because it is a clear measure of the success of a management program. Without a tangible measure of success at the watershed level, the management program has no means of judging the effects of its actions in terms of future salmon production, and no means to determine the urgency of any particular course of action.

Although the existence of an escapement goal and its monitoring program at the watershed level is a necessary condition for an effective sustainable salmon management program, alone it is not sufficient. To be sufficient, escapement goals and their monitoring programs need to be combined with the other elements identified in the Principles and Criteria, including habitat protection and monitoring, stock identification and juvenile assessments.

A clear lesson from the history of Pacific salmon management is that setting an escapement objective, and meeting it, is at least as important as having an escapement objective that is selected to optimize some utility, such as long-term average landings. The National Research Council, NRC, recommended an escapement goal approach to, " reduce the risk of continued loss of salmon populations and production." (Page 295) (NRC 1996). As a step toward escapement goal management, the NRC recommended the minimum sustainable escapement, the MSE, defined as some minimum viable population size below "optimum escapement." A number of spawners less than MSE would serve as a danger signal of management system failure. The MSE may be seen as a particular case of the more general approach of Eggers (1993, Table A - 9). In studies of the effects of failing to meet escapement objectives under conditions of normal variability in management errors and stock size, Eggers (1993) found that a fairly broad range of escapements was expected to deliver future salmon production near maximum sustained yield. In many localities, the Alaska Department of Fish and Game now manages under guidelines that prescribe a range of escapements as the management objective.

In a harvest decision context the escapement goal approach has the distinct advantage of providing a clear signal to the public of the reasons for harvest control actions. Far from the scientific methods (Eggers 1993; Schnute and Kronlund 1996; Walters and Parma 1996) used to produce the goals, the escapements themselves are readily apparent to all the sectors of the public as spawning grounds full of spawners, and associated wildlife such as grayling, trout, bears and eagles. Making the link in the public consciousness between the fishing regulations and the contents of the spawning grounds is fundamental to success of sustainable salmon management.

II. 1. Escapements are adequately measured

The temporal and geographic magnitudes of salmon spawning escapements are measured in order to protect the diversity of the salmon stock (Mundy 1982; Kapuscinski and Lannan 1986). Measurements are needed to inform managers so that they can regulate fisheries in time and space to avoid lowering genetic or physical diversity by disproportionately impacting any spawning population (Mundy and Mathisen 1981; Mundy 1982; Mundy 1985; Kapuscinski and Lannan 1986; Fried and Yuen 1987; Fried and Hilborn 1988; Mundy, English et al. 1993). Salmon are organized into metapopulations (Mundy, Backman et al. 1995; McPhail 1996; Policansky and Magnuson 1998), so the geographic distribution of the escapement for the stock across the spawning localities of the watershed is important to sustaining production (Berkson 1996).

Escapement goal measurements need to be made close to the spawning grounds, or the measurements need to include stock identification (Grant, Milner et al. 1980; Marshall, Bernard et al. 1987). The escapement goal refers to the numbers of an identifiable group of salmon, called a salmon stock. The number of different stocks of a salmon species, such as sockeye, that exist within a watershed varies. When all of the salmon of a species in a physiographically homogeneous watershed are physically and genetically similar, a single escapement goal would be appropriate (Kapuscinski and Lannan 1986). Stock structure may be more complicated when a watershed contains diverse habitats to which the salmon may become adapted (Adkison 1995). There may be several escapement goals for a species in a single large river system, such as is the case for sockeye salmon in both the Kenai and Copper rivers of Alaska.

II. 2. Escapement goals provide sustained yield

Escapement goals are established to deliver consistent future returns to the extent possible. Salmon fishery managers must deal with the fact that if catches on the cohorts of a salmon stock are large enough for long enough, the long-term returns to the fishery will decline (Hilborn and Walters 1992) (see Hilborn 1992, Chapter 7). While having an escapement goal of any kind is preferable to having none, there is a divergence in the literature about scientific methods used to set escapement goals. There are at least three possible approaches, the statistical, the process, and habitat capacity.

The statistical approach dominates contemporary salmon management. A synthesis of the statistical approach to stock-recruitment models that covers the most widely used models (Ricker, Schaefer, Beverton and Holt) formulations is available (Schnute and Kronlund 1996). The general stock-recruit curve has three parameters; a shaping parameter (gamma), maximum sustainable catch, and harvest rate. This allows the Ricker model to be expressed in terms of maximum sustainable catch and harvest rate, instead of the more typical, but less comprehensible, Ricker parameters, maximum rate of productivity (alpha) and carrying capacity (beta) parameters. As used in setting escapement goals, stock-recruitment models need to incorporate long term trends in weather and habitat conditions, and management error (Eggers 1993; Walters and Parma 1996).

Models of freshwater habitat capacity may also be used to set single species escapement goals when the stock-specific catch and escapement information required for stock-recruitment models is not available, or when some aspect of the life history of the stock may require it. Habitat capacity models offer a process based approach for setting salmon escapement goals that has been shown to work. Habitat capacity models used for sockeye salmon offer the opportunity to link salmon escapement goals to trophic structure of the ecosystem (Koenings and Burkett 1987). For example, to compare stock-recruitment and habitat capacity methods, three methods were used to estimate sockeye salmon escapements for maximum production (S max) for sockeye in Chilko, Quesnel and Shuswap Lakes of the Fraser River system of British Columbia, Canada (Hume, Shortreed et al. 1996). The methods were 1) effective female spawners and adult returns using Ricker stock-recruit analysis, SR, models, 2) effective female spawners and fall fry (fry models) and 3) photosynthetic rates (PR) model, a modification of an Alaskan sockeye production model, the euphotic volume model (EV) (Koenings and Burkett 1987). The findings in the Canadian lakes were that the PR models that maximize sockeye salmon production based on photosynthetic rates (euphotic volume) produced accurate predictions with only two years of data, whereas stock-recruit approaches needed longer time series to be effective (Hume, Shortreed et al. 1996).

Neither the stock-recruitment approach nor the habitat capacity approach explicitly recognizes the roles of salmon escapements in the functioning of the ecosystem, a prime concern of Principle II (Table 1). A process based approach (Roughgarden 1998) incorporates data on stock and recruitment, but adds other biological attributes, such as fecundity, and oceanographic processes as they may influence the rate of change in production relative to population size. The production function is derived by combination of the biological and physical processes that define the production of biomass. On the negative side, such approaches have been derided as “physics envy” (Hilborn and Ludwig 1993), because of the time and expense often involved in validating such models. Process models for salmon are expected to become increasingly feasible, as technology for collecting biological and other oceanographic data improve.

It may be feasible, however, to set escapement goals independent of stock-recruitment and habitat capacity models through direct measures of the relation between an escapement and its contribution to other constituents of the freshwater ecosystem. The basic concept is that bodily content of an isotope of marine origin, e.g. marine nitrogen, in juvenile salmon may be related to spawning stock size, and to productivity (Bilby, Fransen et al. 1996).

The ecological, or multiple species, approach to setting salmon escapement goals is a relatively new concept, although contribution of salmon to maintenance of biogeochemical cycles of ecosystems within which it occurs has been recognized for some time (Mathisen 1972; Kline Jr., Goering et al. 1993). The escapement goal would be set at levels that support a particular average or range of diversity of benthic invertebrate fauna, or levels of marine nitrogen in juvenile fish, invertebrates, aquatic and riparian plants (Bilby, Fransen et al. 1996; Piorkowski 1997).

One aspect of Piorkowski’s (1997) study that could be especially important to determining the role of salmon escapements in the aquatic ecosystem is the role of salmon carcasses in determining microbial species composition and diversity. Microbial composition determines the ability of the stream ecosystem to utilize the salmon carcasses. There is a control feedback loop on salmon productivity whereby import of nutrients and food energy to the lotic ecosystem may be retarded in systems that have been denuded of salmon for any length of time.

II. 3. Escapement goal ranges incorporate uncertainty

Escapement goals that support sustainable fisheries are dynamic quantities. The long-term returns actually achieved from any fixed spawning escapement management approach is conditional on many variables, including climate, and management error in achieving the escapements (Table A - 12) (NRC 1996). For example, Eggers (1993) found that salmon escapements near the lower end of the maximum sustained yield (MSY) escapement value would achieve long-term single-stock harvest objectives nearly as well as the MSY escapement level itself. More specifically, Eggers found that escapement goal ranges about the width of the MSY escapement level that ran from eighty percent of the MSY escapement goal to 1.6 times the MSY escapement goal level were likely to keep the long-term average catch within 90% of MSY. Eggers also noted that the relevance of his findings would have to be evaluated for each fishery to which it was applied.

In order to understand and monitor the impacts of the salmon fishery on the ecosystem it is necessary to understand the relation among production of salmon and other species in the ecosystem. Advances in understanding the role of salmon carcasses in driving the functions of the freshwater ecosystem leave open the possibility of setting escapement objectives in order to provide for primary and secondary production, and for other species of invertebrates and vertebrates. Indicators such as changes in water chemistry (Brickell and Goering 1970) and the chemical composition of associated plants and animals (Bilby, Fransen et al. 1996) have already been used to measure the interactions of the salmon with its freshwater ecosystem. These same indicators could be used either as escapement objectives, or as auxiliary information to escapement counts.

Climate (Beamish and Bouillon 1993) and status of freshwater spawning and rearing habitats (Bisson, Reeves et al. 1996) are also primary determinants of salmon productivity. Long and short term changes in the weather, and natural and man-made changes in the amount and qualities of habitat all contribute to the dynamic nature of escapement goals.

II. 4. Escapement goals are met

The degree of error in achieving escapement goals has an important effect on the long-term production to be derived from a management program (Eggers 1993; Walters and Parma 1996). Having the right number of spawners in a watershed is not sufficient to sustaining long-term production unless the geographic and temporal distribution of spawners is appropriate to the full diversity of salmon populations in the drainage (Kapuscinski and Lannan 1986). Salmon populations are distinguished by spawning in different localities, as well as by spawning in the same general localities at different times of the year, so both types of diversity are included in this criterion.

II. 5. Fishing mortality is known

Mortality is cumulative throughout the life of the salmon cohort, so the more that is known about when, where, and how much mortality is being inflicted, the better prepared managers will be to provide regulations appropriate to sustaining salmon populations (Hilborn and Walters 1992; Walters and Parma 1996). As used here, “fishing” includes all human sources of mortality, so a management program needs to know not only the immediate mortalities of adults and subadults inflicted by traditional fishers (commercial, subsistence, recreational), but also the losses of eggs and juveniles due to habitat degrading activities. Losses, including catches need to be subject to stock identification programs (Marshall, Bernard et al. 1987; Utter, Seeb et al. 1993).

As pointed out by Walters (1996b), salmon management takes place on three time scales, short-term (harvest season), medium-term (salmon generation length), and long-term (decadal time scales for habitat-climate changes). Mismanagement can occur when managers focus on gathering information from one time scale to the exclusion of the others (Walters 1996b). Mortalities appropriate to all three time scales need to be used by managers for setting and meeting escapement goals appropriate to sustainable salmon management.

II. 6. Protection of non-target stocks or species

Ecosystem management approaches require coordinated utilization of multiple species and habitats (Sedell, Reeves et al. 1996; Williams and Williams 1996). Escapements need to be met in a manner consistent with protection of non-target stocks or species. Stocks and species other than the stock with the escapement goal that incur mortality in the fishery need to be afforded the same protections as the target stock.

II. 7. Phenotypic and genetic characteristics understood

Escapement data also need to answer questions about the protection of the genetic diversity of the stock. Indeed, the origin of the practice of identifying stocks of salmon resides in the presumption of genetically based differences in stock productivity and other biological characteristics (Ricker 1954; Ricker 1972; Adkison 1995). Selection by the fishery against heritable traits of adaptive significance, such as body size at age, is to be avoided (Ricker 1972; Kapuscinski and Lannan 1986). Consequently, escapement data need to include measures of body morphology and other biological attributes potentially under selection through human activity. Genetic traits such as proteins from blood and other bodily tissues that are not likely subject to natural selection should be surveyed in order to document geographic patterns that may contribute to understanding of the evolutionary histories of salmon populations among localities (Waples and Teel 1990; Utter, Seeb et al. 1993; Adkison 1995).

For small salmon populations, the sex ratio of the population can be important to determining the effective breeding number (Tave 1986), but for very large populations, the sex ratio is probably more important for determining the potential egg deposition for production estimation. The definition of “small” and “large” are somewhat arbitrary, since the chances of loss of genetic information increases sharply as the salmon population approaches zero (Waples 1990; Adkison 1995). Although the loss of genetic diversity in large commercially exploited Alaskan salmon populations may appear unlikely, this is by no means the case for relatively small salmon populations from small independent drainages that may appear as non-target landings and collateral mortalities in large salmon fisheries. The issue of protection of genetic diversity needs to be explicitly recognized as part of any sustainable salmon management program (Riddell 1993; Utter, Seeb et al. 1993; Adkison 1995; NRC 1996). As is generally the case for sustainable fishery management principles, the management actions that constitute recognition will depend on the circumstances of the fishery.

II. 8. Understanding the role of salmon in the ecosystem

Salmon escapements provide not only for the future production of salmon, but they also contribute to an influx of nutrients needed to sustain stream and lake productivities (Bilby, Fransen et al. 1996). In the long-term, protection of Alaskan fisheries resources will require extending the protection now afforded to targeted commercially important salmon stocks to ecosystem functions (Mangel, Talbot et al. 1996). In process-oriented conservation (Mangel, Talbot et al. 1996), production of ecologically central vertebrate species such as salmon is combined with measures of the production of other species, and measures of the flow among trophic levels of common elements such as nitrogen and carbon, to identify and protect ecological processes such as nutrient transport. Applications of ecological process measures in Alaskan salmon systems have shown the feasibility and potential importance of such measures (Mathisen 1972; Kline Jr., Goering et al. 1990; Kline Jr., Goering et al. 1993; Piorkowski 1997), as have applications outside of Alaska (Bilby, Fransen et al. 1996; Larkin and Slaney 1997).

In studies of a small Alaskan stream containing chinook salmon, Piorkowski (1997) obtained data to support the hypothesis that salmon carcasses can be important in structuring aquatic food webs. Ecological effects of salmon carcass decomposition were measured using observations of fates of carcasses, macroinvertebrate community structure, stable isotope ratios significant of relative amounts of marine-derived nitrogen and terrestrial-derived nitrogen, and dissolved inorganic nitrogen from groundwater. Macroinvertebrate communities in streams receiving carcasses were more diverse compared to streams not receiving inputs. Many other taxa responded positively to enrichment, while some responded negatively.

II. 9. Population trends understood

Understanding population trends of the salmon and allied species in relation to the status of habitats and climate is essential to sustainable salmon management (see Criterion I. 1. A.). Population trends of juveniles in relation habitat utilization are particularly important to habitat protection and restoration efforts (Walters 1996b). Understanding population trends is key to assessing the long-term health of salmon populations (Baker, Wertheimer et al. 1996; Huntington, Nehlsen et al. 1996).

Principle III. Harvest with caution

It is now becoming widely recognized that limitations on information and lack of enforcement should sharply limit the ways in which sustainable natural resource extraction may be conducted (FAO 1995; Mangel, Talbot et al. 1996). If it is reasonable to assume that major uncertainties in how ecological systems respond to management actions will always be with us, then the way in which resource management decisions are made needs to reflect the uncertainties (Ludwig, Hilborn et al. 1993). Making decisions on the use of the salmon resource consistent with the degree of uncertainty requires judicious collection and use of the information from the salmon fisheries and their habitats. Decision making under uncertainty further requires management actions to use the information collected to adapt to changing climate and population levels in ways that provide for sustainable salmon populations (Walters 1986). Harvest and habitat management programs need to be structured to advise decision makers on the chances of success (or failure) associated with an action, and on how to respond to each success (or failure) with additional management actions. This iterative process is known as adaptive management (Holling 1978).

In the Salmon Fishery, changes in spawning and rearing habitats, including changes induced by climate**,** are translated into harvest management actions that protect stocks from excessive harvest. The amount of salmon the ocean can produce changes through time in response to changes in climate (Beamish and Bouillon 1993). Climate changes occur on time scales that range from decades to millennia (Pearcy 1996). Sustainable salmon management requires that managers identify trends in marine productivities relevant to their stocks in order to know how to limit harvest to levels appropriate to sustaining production. Sustaining salmon production is a dynamic process of ensuring that the size of harvests do not exceed the productive capacities of the stocks. Productive capacity is dependent on the qualities of the habitats, as influenced by climate. Productive capacities change in response to natural and man-made alterations of the fresh water and marine habitats. Long-term and short-term climatic events combine to enhance the dynamic nature of the harvest management process in the Salmon Fishery.

There is broad consensus in the scientific literature that regulation of the use of living resources must be based on understanding the structure and dynamics of the ecosystem of which the resource is a part. Further it must take into account the ecological and sociological influences that directly and indirectly affect resource use The supporting principles from the literature are Food and Agriculture Organization 6.4; 7.2.3 (FAO 1995), AFS North American Fisheries Policy 4 (Starnes, Jiminez et al. 1995), Principles for the Conservation of Wild Living Resources IV (Mangel, Talbot et al. 1996). Under sustainable salmon management it is the responsibility of managers to understand the current state of the salmon producing systems, which requires managers to understand the ecosystem well enough to know where to look for information. Monitoring and evaluation of the salmon, their spawning and rearing habitats, and their associated biota are key to successful salmon management. The intensity and costs of monitoring and evaluation necessary to sustain salmon production is directly proportional to the number of humans using the salmon, the number and geographic extent of human activities that degrade salmon habitat, and the magnitude of negative impacts of climate and natural disasters on salmon.

The effects of habitat utilization introduce major uncertainties into the process of setting harvest levels in the long-term. The following effects are known to be significantly negative with respect to harvestable levels of salmon, however exact quantification is often problematic;

- effects of logging and associated roads on salmon habitat productivity
- effects of cumulative impacts of urban, commercial and residential development and oil spills in the nearshore marine habitat
- effects of reduction in water quality and quantity due to hydroelectric power, water export, community water supplies, extensive logging within a watershed, mixing zones
- unknown effectiveness of Best Management Practices to minimize non-point source pollution (Espinosa, Rhodes et al. 1997)
- the limited extent of habitat-related knowledge could be used to improve accuracy of stock production estimates, stock escapement goals, and status of individual habitats
- effects of habitat blockages to fish passage by culverts that are neither permitted nor monitored

III. 1. Precautionary approach to habitat alteration

It is neither feasible nor desirable to attempt to measure all consequences of perturbing ecosystems (Ludwig, Hilborn et al. 1993). When precise measurements are unavailable, scientists are often able to infer the probable consequences to salmon of habitat degrading activities. Under the precautionary approach (Garcia 1994), human actions that have a reasonable chance of doing long-term or irreversible damage to salmon producing habitat are not consistent with sustainable salmon management. Similarly, salmon fisheries on stocks originating from habitats with a reasonable chance of incurring long term or irreversible damages would not be sustainable. Under Walters' (1996b) definitions of time scales applicable to fisheries information, short-term is less than a salmon generation, and long-term is more than a decade.

Although the terms, precautionary approach, and precautionary principle, have been used in the same way in marine fisheries literature (Lauck, Clark et al. 1998), it is important to note that the literature origins of the two terms are different. The origin of the precautionary approach in fisheries (FAO 1995b) is apparently the precautionary principle in marine pollution law (Garcia 1994b). The precautionary principle is derived from marine pollution law (Cameron and Werksman 1991). The principle appears to have emerged in marine pollution law as a response to the lack of both precision and accuracy in scientific estimates (Hey 1993). When the long-term consequences of making a decision on the environment by accepting a false scientific assessment which is actually true are likely to be severe, understanding the precision of the estimate is extremely important to environmental protection (Peterman and M'Gonigle 1992). One interpretation of the precautionary principle points out the need to reverse the burden of proof from scientists onto the polluters, in order to put environmental protection first (Earll 1992).

III. 2. Precautionary approach to harvest

Achieving a realistic balance of management capabilities against the intensity and extent of fishing is part of what is known as the precautionary approach (Garcia 1994; Caddy 1995). In a precautionary context, absence of adequate scientific data should not justify delaying, or not taking, actions to conserve target species, associated or dependent species and non-target species and their environment (FAO, 1995; Table A - 5; 6.5). Incomplete or inadequate data are frequently the norm in salmon management situations, as in most natural resource management activities (see Ludwig et al. 1993). In some cases, conservation actions may need to be based on analyses of the probable consequences to salmon of fishing, especially when long-term, or irreversible, consequences are more likely than not.

The precautionary approach, although relatively new to international fisheries literature, has been institutionalized in Alaskan in some localities since statehood. In fisheries for a number of the major commercially important salmon stocks, such as Bristol Bay sockeye salmon, the concepts of the precautionary approach are familiar (Minard and Meacham 1987). In such Alaskan fisheries, a precautionary approach to fisheries management places the responsibility on harvesters to cut effort promptly once reduced spawning stocks are identified by managers. Scientists in the public involvement process have previously satisfied the burden of proof where they have presented and justified levels of sustainable harvest. When resource assessments are uncertain, the Alaskan managers of these fisheries have the option of restraining harvest until better information allows them to be more certain about the consequences of fishing.

III. 3. Decisions based on the best available information

The standard of basing actions on the best available scientific data is part of most significant environmental protection statutes in the United States, including the National Environmental Policy Act, The Endangered Species Act, and the Magnuson-Stevens Sustainable Fisheries Act. The best available scientific data standard is also widely accepted internationally (MSC, 1996; Table A - 3; 2.3; FAO, 1995; Table A - 5; 6.4, 6.5; Table A - 6; 7.1.1, 7.2.1)

III. 4. Best available information updated and peer reviewed

The best available scientific information on the status of populations and the condition of their habitats is routinely updated and updates are subject to peer review. The status of natural resources change through time, so the best available information is often the most recent. Maintaining management capabilities for salmon requires periodic renewal of information on the status of populations and the condition of their habitats (Starnes, 1995; Table A - 8; 4). Scientific data and analyses are subjected to the scrutiny of independent peer review to test their reliability.

III. 5. An ongoing research program exists

An ongoing research program is essential to improve scientific and technical knowledge of fisheries including their interactions with the ecosystem. A research program is a key attribute of a sustainable salmon management program. The standard of the “best available information” should never be confused with the lack of available information. As noted in Criterion III.2, absence of adequate scientific data should not justify delaying, or not taking, actions to conserve target species, associated or dependent species and non-target species and their environment (FAO, 1995; Table A - 5; 6.5). When information is lacking, the precautionary approach is to weigh the probable long-term consequences of management action against the conservation risks of doing nothing.

III. 6. Fisheries development based on resource assessments

Initiatives for new fisheries need to be supported by information on the sustainability of the proposed actions. Consequences of the proposed actions need to be developed from analysis of relevant historical data if available, or on the basis of new data from experimental fisheries if necessary. The ability of the resource to sustain the new fishery needs to be developed prior to implementation of the fishery.

Principle IV. Establish and apply an effective management system

Protecting salmon populations and habitat, providing escapements, and limiting harvests (Principles I - III) all require an effective management system for implementation (FAO, 1995, 6.8 & 7.1.1; Starnes, 1995, 2; MSC, 1996, 3; Mangel, 1996, IV). Effective management systems that provide long-term protection for the salmon also provide substantial net economic benefits to society (Eggers 1992). Consequently, an effective management system is part of retaining public support (Principle V). Knowledge needs to be translated into actions in the form of effective fishing regulations, enforcement of fishing regulations, habitat protection regulations, and enforcement of habitat protection regulations. As is the case with any public process, the management system that helps to sustain salmon production needs to be subject to periodic performance evaluations that measure how well objectives are being met.

IV. 1. Management objectives appropriate to scale and intensity of use

The distribution of salmon stocks among fisheries can produce a very large range of scales and intensities of use for each stock (see Figure 2). Scale and intensity of use may be defined by a variety of factors related to the fraction of the stock removed by a unit of fishing effort in unit time, catchability (Ricker 1975), the number of units of effort, and the proportion of the stock that is removed by fishing each season. Large-scale fisheries have the ability to remove a very large proportion of the stock in a short amount of time, and the catch rate and efficiency (Hilborn and Walters 1992) of the individual vessels or dominant vessel class are typically high. High intensity fisheries typically remove a large fraction of the total stock each season.

As may be obvious, large scale, high intensity fisheries pose the greatest risk to both short and long-term stock abundances, and therefore require large scale, high intensity management programs. As may not be obvious, even small scale, low intensity salmon fisheries also require careful management scrutiny, because of the migratory nature of the salmon species. The most important challenge in salmon management is created when the cumulative catches of a series of low intensity component fisheries over the life cycle of the cohort produces the effect of a single, very high intensity salmon fishery. The challenge is made daunting by the fact that the component fisheries (Figure 2; 2.2, 2,6, 2.10, 2.14, 2.18) may have no single management authority. In sustainable salmon management, the fishery is seen as the sum total of the harvest actions during the life of the cohort. The sum of the component salmon fisheries across cohorts from the stock defines the scale and intensity of use for the stock.

It has been argued that it is reasonable for salmon harvest management to neglect stocks that form very small parts of the total harvest (Lloyd 1996), and that the efficacy of a harvest management action to contribute to attaining fixed escapement goals for a given stock is inversely proportional to the proportion of that salmon stock in the catch of the fishery (Lloyd 1996b). Although such “weak stock” arguments may be considered pragmatic within the context of a component fishery, they are not valid in the context of the broader salmon fishery definition (Figure 2) and requirements for sustainable salmon management (Table A - 1).

The lack of validity in the “weak stock” arguments (Lloyd 1996 and 1996b) as they apply to the salmon fishery is evident from the recent negative experience of the Southeast Alaska chinook troll fishery. The southeastern chinook troll has taken devastating cuts in its annual chinook quota during the last several years to protect the federally threatened Idaho fall chinook stock that fishery management agencies once decided was too weak to be “significant.” The Snake River fall chinook is caught in small numbers in the southeastern Alaska troll fishery. Management agencies (States of Idaho, Oregon, Washington, and the Columbia River treaty fishing tribes) responsible for the escapements of Snake River fall chinook, did not take steps to protect this “weak” stock because it was considered a relatively minor part of Columbia River basin chinook production. Unfortunately for the southeastern trollers, the provisions of the Endangered Species Act did not allow another agency, the National Marine Fisheries Service, to treat the Idaho fall chinook as a weak stock (Waples, Jones Jr. et al. 1991; Myers, Kope et al. 1998).

IV. 2. Management objectives subject to periodic review

Development of management plans and evaluation are essential parts of the management cycle for salmon fisheries (NRC 1996). Applications of knowledge from biological sciences to salmon management are advancing rapidly in the wake of listings and proposed listings of salmon populations under the Endangered Species Act (NRC 1995). Periodic review is necessary to see that the best available scientific information is incorporated into the management program (Starnes, 1995; Table A - 8; 4). Before review can occur, the components of the management program need to be clearly explained for the benefit of the public and the Board of Fisheries process (Table

A - 1; Criteria IV. 4, V. 1, V. 2). During evaluation the information available and the results of the salmon management program are used to develop the next generation of information gathering and management plans (Walters 1986).

Policies for managing mixed stocks are essential to sustainable salmon management. The degree to which the aggregates of salmon that are harvested together in mixed stock fisheries share genetic traits, such as productivities (return per spawner), is an important determinant of the consequences of harvest management actions (Paulik, Hourston et al. 1967; Hilborn 1985; Eggers 1993; Policansky and Magnuson 1998). Consequently, it is important to consider the degree of correlation among salmon productivity parameters (i.e. Ricker's α) when determining the harvest control policies applied to salmon (Eggers 1993). When there is a lack of correlation among the groups of salmon to which a common harvest rate appropriate to maximum sustained yield (MSY) for the mixture is applied, the risk of extirpation for stocks of low productivity exists (Paulik, Hourston et al. 1967). Managing genetic resources also occurs during the process of mixed stock fishery management (Kapuscinski and Lannan 1986), and in stock definition (Utter, Seeb et al. 1993).

IV. 3. Effectiveness of habitat protection laws evaluated

Periodic review of habitat management effectiveness is essential to assess the overall effectiveness of sustainable salmon management. Effective protection of the environments on which target species depend is universally accepted as essential for long-term sustainable fishing (FAO 1995; Olver, Shuter et al. 1995; Starnes, Jiminez et al. 1995; Mangel, Talbot et al. 1996; MSC 1996).

IV. 4. Government openly evaluates fishery management actions

Access of the public to timely information on the consequences of habitat alterations and fisheries on catches, escapements, and collateral mortalities of salmon and allied species is the cornerstone of an open process of evaluating the effectiveness of fishery management actions (FAO 1995). Access of the public to post-season evaluations of the habitat and harvest management programs, such as reports to the Board of Fisheries, ADF&G Annual Management Reports, and reports of the National Forest to Congress, is one means of access to data. Posting of data from habitat and fisheries monitoring programs on web sites and at the local government offices is another example of allowing adequate public access.

IV. 5. Management separates biological and allocation issues

Guidance to management on how to discriminate between biological and allocation (policy) issues is a key part of an open evaluation process. Policy makers need to specify biological guidelines in management plans that also specify allocations.

IV. 6. Management actions verified and corrected

The extent to which information gathered by the management program is actually used to validate and to improve the management program is a test of the use of adaptive management (Holling 1978). As a first step, the management program must be able to gather the kinds of information that makes evaluation possible, and the second step is to use the data to examine and to adapt the programs to the circumstances described by the data. Adapting procedures to remedy deficiencies is a routine function of effective resource management (Walters 1986).

IV. 7. Consistency of management with statutes

Evaluation processes determine the extent to which the outcomes of management were consistent with legal requirements. For example, a process should routinely examine fisheries management outcomes for consistency with Alaska Board of Fisheries regulations. Board regulations are examined during promulgation for consistency with Alaska statutes (Waste 1992). As an example, regulations would be evaluated for consistency with the priority for subsistence use called for by statute.

IV. 8. Management is timely and adaptive

Timely action is critical to successful salmon management because of the nature of the life cycle (Mundy 1985). Adult salmon may be available to coastal fisheries for only a few weeks each year, and the economic value of the catch may change rapidly as the fish mature. Timely actions are essential to protect early life history stages during critical time windows on the spawning grounds, and in migrations between spawning and rearing habitats. Working in an adaptive fashion means gathering and using scientific information to tailor management actions to the resource (Walters 1986; Walters 1996b). Informing change is the essence of adaptive management (Holling 1978).

IV. 9. Management has clear authority to protect salmon and habitat

The degree to which an effective salmon management system is in place is reflected in the statutory authority of the management agencies. Authority for management agencies to take action to limit harvests of all kinds, including harvests in both fisheries and habitat alterations, is a hallmark of an effective sustainable salmon management program.

IV. 10. Management of wild and hatchery interactions

The challenges of integrating hatchery technologies into an ecosystem approach to sustainable salmon management are substantial (Kapuscinski 1996). The extent to which management programs are addressing these challenges is an important test of sustainable management capability.

A primary challenge is to understand the potential interaction of hatchery production with natural production to alter the genetic and biological diversity of watersheds (Kapuscinski 1996). Concerns about the desirability of interbreeding of potentially altered hatchery salmon with wild salmon are based on historical problems with the misapplications of salmonid aquaculture (NRC 1996). For example, selective actions within hatcheries have been shown to have the potential to alter the disease resistance characteristics of steelhead and coho salmon populations that are critically important for survival (Buchanan and Sanders 1983; Hemmingsen, Holt et al. 1986).

A further category of challenge is to understand the extent to which hatchery production needs to be synchronized with changes in ocean carrying capacity to avoid adverse consequences for the productivities of wild stocks (Pearcy 1996). Although a 1992 review found no apparent evidence that hatchery stocks are changing the gene pool of Alaska salmon (Thomas 1993), trends in ocean productivities, as influenced by long-term and short acting climatic events (Francis and Hare 1994), causes concerns about competition between hatchery and wild salmon in the marine environment. Records of declines in survival or growth of wild salmonids correlating with increases in abundance of their hatchery counterparts are fairly common (Thomas 1993; Fresh 1996). If the production of hatchery smolts remains constant, or increases, it is reasonable to be concerned that marine competition from hatchery salmon could depress wild stocks even further and more precipitously than would be the case in the absence of such competition.

IV. 11. Effective law enforcement

Statutory authority to implement harvest controls, including controls on habitat degradation is only meaningful to the extent that management incorporates appropriate procedures for effective compliance, monitoring, control, surveillance and enforcement. It is axiomatic that laws have effect only to the extent that they are supported by regulations and tools for enforcement. In concert with protection of ecosystem functions, the need for better enforcement of fishing regulations that has been identified on a global scale (Caddy 1995) seems particularly relevant to Alaskan salmon fisheries. Alaskan scales of geography are very large, so the challenge of providing accurate information about resource status, and of equitably enforcing fishing and habitat use regulations, is accordingly daunting.

IV. 12. Multilateral cooperation in research and management

Close cooperation among management agencies within and across state and national boundaries in daily operations, and more thorough integration of management functions, are essential to the long term well being of Pacific salmon populations (Hughes 1996). Cooperation and integration of management processes are especially difficult when salmon cross international boundaries (Jackson and Royce 1986; Roos 1991). The extent to which multilateral cooperation is being practiced is therefore an important test of the sustainable salmon management program.

IV. 13. Transboundary law enforcement

The degree of multilateral salmon management cooperation is tested by the extent to which procedures for effective compliance, monitoring, control, and surveillance exist.

IV. 14. Transboundary assessment and management

The degree of multilateral salmon management cooperation is tested by the extent to which effective joint assessment and management arrangements are in place for transboundary stocks (FAO 1995; Starnes, Jiminez et al. 1995).

IV. 15. Management is sufficiently funded for information gathering

Statutory authority to implement harvest controls, including controls on habitat degradation, is only meaningful to the extent that management has access to the resources necessary for collection and dissemination of the information and data necessary to carry out essential functions of management described in the principles and criteria (FAO 1995; Starnes, Jiminez et al. 1995). For example, an open process for objectively evaluating the effectiveness of fishery management actions (Criterion IV. 7) is directly dependent on management having the resources to provide the information.

IV. 16. Management is sufficiently funded for implementation

Statutory authority to implement harvest controls, including controls on habitat degradation, is only meaningful to the extent that management has access to the resources necessary to implement the sustainable fisheries management principles (FAO 1995; Starnes, Jiminez et al. 1995).

Principle V. Maintain public support and involvement

Although science has a role to play in defining sustainable fisheries management, sustainability cannot be achieved without social and political understanding (Mooney 1998). Sustainable salmon management should observe the rights and long term interests of people dependent on fishing for food and livelihood in a manner consistent with ecological sustainability (FAO, 1995; Table A - 5; 6.2 & 6.5; Starnes, 1995; Table A - 8; 5; MSC, 1996; Table A - 3; 5; Mangel, 1996; Table A - 2; VI). Sustainable salmon management also recognizes that humans, as the recipients of management actions, are a major force in the success of management programs (Ludwig, Hilborn et al. 1993; Mangel, Talbot et al. 1996; Mundy 1996). Sustainable use is an essential benefit of sustainable salmon production. The ultimate goal of the fisheries policy process is to achieve an equitable allocation of the benefits and burdens of conservation for salmon across all of the concerned user groups, fisheries, and jurisdictions. But government powers in the form of regulations are limited, so negotiation among affected parties is an important method of resolving environmental conflicts (Lee 1993).

V. 1. Government provides dispute resolution

The sustainable regulatory process is the art of shaping human behavior to enable the long-term persistence of salmon and their habitats (Mundy 1996). As the proprietor of the resource, government has the authority and responsibility to provide allocation and to resolve disputes over allocation.

V. 2. Public involvement process

Shaping human behavior in a democracy involves an open and fair public involvement process that addresses management and allocation decisions and resolves disputes. The Alaska Board of Fisheries serves as the best available model for a public involvement process that supports sustainable salmon management (Waste 1992; Krasnowski 1997). Within the Board of Fisheries process, salmon managers are required to share their understanding of the consequences of past and proposed actions with the public. Policy makers are required to explain their rationales for conservation and allocation decisions to the public and to receive input from the public.

V. 3. Allocation of the conservation burden

Allocation of the conservation burden within the political process is an essential part of sustainable management of salmon. History indicates that a conscious allocation of the conservation burden must occur if salmon are to survive (Netboy 1980). Although scientific methods are available to estimate the total size of the conservation burden, it is the policy process that must prescribe to whom the burden is allocated. Historically, the burden of conservation for salmon was allocated to fishers alone among the consumptive user groups. Other user groups, such as irrigators, hydroelectric power producers, timber harvesters, and land developers either were not required to share the burden of conservation for the salmon they consumed, or they were required to make monetary compensation in the form of hatcheries. Unfortunately, coin of the realm is not the currency of the burden of conservation. The burden of conservation can only be paid in long-term reductions in mortalities on the salmon stocks being consumed. Lack of payment in the correct currency for the burden of conservation is why so many efforts to mitigate for lost habitat have failed (Netboy 1974; Netboy 1980; Bottom 1996; NRC 1996). Sustainable salmon management requires that consumptive users of the resource share the burden of conservation for salmon throughout the life cycle.

V. 4. Adequately funded public information and education programs

A governmental process provides adequately funded public information and education programs for the public concerning salmon habitat requirements, salmon habitat threats, the value of salmon and habitat to public and ecosystem, natural variability and population dynamics, value of salmon to other fish and wildlife, current status of Alaska fish stocks and fisheries, and the Board of Fisheries process.

V. 5. Dissemination of results in a timely fashion

Access of all interested parties to timely information on the consequences of management actions is essential to maintaining public support and involvement for protection of salmon resources. Timely distribution of management information is also required to support a governmental process for dispute resolution (Criterion V. 1) and for supporting the public involvement process (Criterion V. 2).

V. 6. Understanding sources of mortality among user groups

One reason that habitat degrading and occluding industries have been slow to shoulder their share of the burden of conservation may be the difficulty in measuring the levels of mortality incurred by their actions. In industries where salmon managers have measured or inferred mortalities for salmon over long periods of time, such as the hydroelectric power producers in the Columbia River basin, serious attempts have been made by industry to reduce mortalities on salmon (Mighetto and Ebel 1994).

Sustainable salmon management programs need to constantly promote understanding of where salmon are being lost due to human actions of all kinds. Although recent strides have been made in understanding how to manage watersheds and shape institutions to protect salmon production (Bisson, Reeves et al. 1996; Sedell, Reeves et al. 1996; Williams and Williams 1996), many, if not most, of the watersheds that have been managed for “multiple use” have declined in salmon production, or ceased to produce salmon at all (Henjum, Karr et al. 1994; Espinosa, Rhodes et al. 1997).

CONCLUSIONS

Sustainable salmon management is a scientifically straightforward, but politically tortuous, process of controlling harvests and protecting habitats. The criteria for sustainable salmon management may seem impossible to meet, but such is not the case. Since the criteria are ideals, it is highly unlikely that any fishery would ever meet all of the criteria perfectly at the same time. It is expected that a well managed salmon fishery would satisfy most of the criteria within all of the principles to some extent. In the long-term, it is extremely important to protect salmon habitats and the genetic diversity of the populations. In the short-term, controlling harvest throughout the series of fisheries encountered by salmon is critical to provide suitable escapements. Fisheries and habitat degrading activities need to be restrained when it is more likely than not that escapement goals are not going to be met.

In practice a very broad range of Alaskan salmon harvest management capabilities and fisheries now appear to meet the standards of sustainable salmon management to varying degrees of fidelity. The actual extent could only be determined by finishing the framework and applying it to the fisheries. Although there will be substantial secular differences among fisheries that will affect the degree of difficulty in identifying the stocks in each fishery, it is expected that all current Alaskan salmon gear types in all current localities, including coastal troll fisheries, net fisheries in marine transit areas, as well as net fisheries near to, and within the mouths of rivers, could satisfy this definition of sustainable salmon fishery management to some degree.

It remains an open question as to whether the sustainable salmon management can be maintained, improved, and implemented in enough localities within the range of the Pacific salmon to avoid the fate suffered by Atlantic salmon in the northeastern United States (Netboy 1974). In those fortunate, but few, areas with reasonably pristine habitat, little human development, modest levels of bycatch, and effective management programs, salmon should be able to persist indefinitely. Unfortunately, even supposedly pristine freshwater habitats may have been rendered less productive for salmon by the effects of chronically low escapements (Piorkowski 1997). Without information on historical escapements and the nature of food webs in supposedly pristine areas, there is no room for complacency on the part of scientists and policy makers. When only the adult catches and escapements are known, not even the most pristine areas should be considered free of risk for long-term loss of productive capacity.

Alaska is presently blessed with many strong and diverse salmon populations. The bounty is not reason to neglect strengthening the harvest and habitat management and social and political institutions concerned with salmon management. Too often in the past in Alaska and elsewhere the fact that salmon were numerous was used as an excuse to neglect funding and improving management programs (Netboy 1974; Netboy 1980). It is an unfortunate fact of history that the money spent on salmon research programs is inversely proportional to the abundance of salmon. As runs begin to decline, more money is spent on management, and as runs are extinguished, even more money is spent on recovery efforts. Would it not be more intelligent to spend a fraction of the money now being spent on salmon recovery on implementing sustainable salmon management programs? Under sustainable salmon management, perhaps Alaska could grow in population and develop its natural resources without the fishers and the other taxpayers being left to pay a high price for “salmon recovery.” Perhaps.

DEFINITIONS

Bycatch - Portion of the fish caught that discarded into the water dead. Note that the international agency that coordinates most North American coastal troll harvests, the Pacific Salmon Commission, terms bycatches, incidental catch or incidental mortality (PSC 1993). Also note that bycatches are not retained, and so they are not sampled for stock composition by sampling projects located at the port of landing.

Catches, Target and Non-Target Harvests: Strictly speaking, catch refers to all salmon killed by the fishery, whether landed or not. For the sake of clarity, catch may be split into a number of categories, including landings. Clarity is important, but by no means easy to achieve, when naming categories of salmon killed by the fishery (Alverson, Freeberg et al. 1994; Hall 1996). In principle, sustainable management requires knowledge of total fishing mortality, as the sum of all the deaths attributable to the fishery (Alverson and Hughes 1996). The classification system proposed by Hall (1996), but not the terminology, has been adapted to the Salmon Fishery model. Hall's (1996) classification of bycatch concepts is useful, however the terminology is not reproduced here because it is inconsistent with historical literature on population dynamics such as Ricker (1975). The concept of collateral mortality, as fish killed but not retained by the gear, is most useful to salmon fisheries management.

Classification of bycatch by Hall (1996)
- Capture - retained by the gear
  - Catch - retained for processing
    - Target catch - catch of main species sought by fishers
      - rejects - unsold catch
      - marketable catch
        - processing waste
        - yield - sent to consumers
    - Non-target catch - retained and sold
  - Bycatch - portion of the capture discarded at sea dead
    - Target bycatch
    - Non-target bycatch
  - Release - returned to the water alive with expectation of survival
    - Target release
    - Non-target release
- Collateral Mortality - killed by the gear but not retained by the gear

Lost-gear mortality - killed by fishing gear not under control of fishers
All of these categories are referred to in the literature as bycatch.

Cohort: Salmon of the same age. In almost all cases, a cohort consists of salmon that were fertilized eggs in the same calendar year or other unit time. Spawning activity in some populations may extend across calendar years. With some exceptions, members of a cohort mature and spawn at different ages, two to eight years after the eggs are fertilized. Pink salmon mature two years after egg fertilization almost without exception, and coho salmon spawners are usually nearly all the same age, which varies with locality.

Collateral Mortality: Fish killed but not retained by the gear. See also catches. Collateral mortality is also called incidental catch, and it may be included in bycatch by some authors (Alverson, Freeberg et al. 1994). For example, steelhead trout taken in a commercial salmon fishery would fall in the category of bycatch if they were to die after being caught. Caught sockeye salmon that drop out of gill nets in a sockeye salmon fishery before they can be landed are in the category of collateral mortality or incidental catch. In the salmon fishery there is a reason to distinguish between bycatch, as non-target landings and incidental mortality, and collateral mortality, since salmon bycatch may be landed, but incidentally harvested salmon are not.

Fishery, Salmon: The salmon fishery is the sum total of the harvest actions during the life of the cohort. A component salmon fishery is identified by locality, species or stock, and gear type. Cook Inlet central district sockeye drift gill net, Lower Yukon fall chum gill net, and Bristol Bay Naknek section sockeye set net are examples of Alaskan component salmon fisheries. The sum of the component fisheries across cohorts from the stock defines the scale and intensity of use for the stock.

Species of Salmon: The term species refers to the biological species of the Pacific salmon occurring in North America. The biological species of Pacific salmon harvested in Alaska are all in the genus *Oncorhynchus* (Robins, Bailey et al. 1980); *O. gorbuscha*, pink (humpy) salmon, *O. keta*, chum (calico, dog) salmon, *O. kisutch*, coho (silver) salmon, *O. nerka*, sockeye (red) salmon, *O. tshawytscha*, chinook salmon. Since the publication of Robins et al. (1980) the steelhead trout has been accepted as a member of this genus under the binomial, *O. mykiss*.

Stock, Fishery: A fishery stock is "the fish spawning in a particular lake or stream (or portion of it) at a particular season, which fish to a substantial degree do not interbreed with any group spawning in a different place, or in the same place at a different season. " (Ricker 1972). Within the context of the U.S. Endangered Species Act, salmon stocks are composed of geographically bounded collections of distinct population segments, or evolutionarily significant units (Waples 1995). A salmon stock, as used here, is the part of a of population on which management actions are taken (Ricker 1975). A population, as it is widely used in fisheries management literature (Cushing 1975; Ricker 1975) , is a collection of spawning aggregates of a single species whose individuals share common growth, fecundity, age structure, mortality schedules, and other vital statistics. In this usage, the commonality of the vital statistics is characterized by low variance. Geographically contiguous clusters of salmon populations that share a common evolutionary history are also known as metapopulations (Mundy, Backman et al. 1995; McPhail 1996; NRC 1996).

The fisheries stock definition is consistent but not synonymous with, the definition of a deme (NRC 1996). The term deme is properly applied to a freely interbreeding population spawning in a single locality (NRC 1996). In practice, stocks are aggregations of demes characterized by the sites from which their individual escapement counts are obtained. Implicit in the stock definition is the belief that stocks are substantially reproductively isolated over short time frames of 10 to 20 average salmon generations (50 to 100 years). Within short time frames, straying from the home stream leading to successful reproduction in other localities is believed to be relatively rare between stocks, but common within stocks. Over longer time periods successful straying among stocks is highly likely, as demonstrated by comparison of the present geographic distribution of Pacific salmon to the geologic history of glaciation.

In a practical sense an Alaskan salmon fishery stock is composed of many spawning aggregates, also called races (Figures 1 and 2), or demes (NRC 1996) of a single biological species that spawn in a connected system of watersheds, and that share a common life history. Also as a practical matter, how the individual spawning aggregates, or demes, of salmon are grouped to form stocks depends on the resources available to the management agency. Low budgets mean stocks that cover big geographic regions. In the future increasing demands of allocation and improved biological knowledge may make it desirable, or essential, to designate smaller stock groupings (see the discussion in Adkison 1995). To meet the present demands for sustainable salmon management in Alaska, the stocks established in the Annual

Management Reports, AMR, of the Alaska Department of Fish and Game appear adequate. Also see the management unit definitions in Baker (1996).

As indicated in the AMR series, fishery stock definitions follow patterns based on the biology of the species, and the physiography of the watersheds in which they occur. Alaskan chinook salmon stocks are collections of spawning aggregates associated with independent tributaries of marine waters, such as the Yukon, the Nushagak, Naknek, Susitna, Kenai, Copper, Situk, Chilkat, and Taku, among many others. Sockeye are also identified by the name of the main tributary that drains one or more rearing lakes, such as Igushik, Wood, Kvichak, or by the name of the rearing lake, such as Hugh Smith. Chum salmon stocks are identified by independent drainages and may also be identified by timing of adult return from marine waters, such as the summer and fall stocks of the Yukon River. Pink salmon stocks are most often identified by geographic region of origin (districts), since they often spawn in many small independent tributaries, but pink salmon stocks are also known by watershed. Nushagak River, Eastern Prince William Sound, and Northern Southeast (Alaska) are examples of present pink salmon stock groupings. Coho salmon also often spawn in many small independent tributaries in addition to major river systems, so coho stocks may be either designated by rivers, i.e. Kuskokwim, Susitna, or by geographic regions, i.e., western Cook Inlet.

Stock, Genetic: Although recent advances in understanding the genetic structure of salmon populations has permitted new insights into how their potential diversity may be factored into management (Utter, Seeb et al. 1993), the issue of how to apply observed genetic differences to salmon management is complex (Adkison 1995). Adkison (1995) suggests that the question of how prevalent local adaptation is in Pacific salmon populations can be asked as, "How prevalent are strong localized selective pressures?" Yet in addition to unique physical conditions in spawning or rearing habitats, other factors must be present in order for local adaptation to occur. In addition to strong selection, adaptation is facilitated by large and stable population sizes, equal reproductive success among individuals, and overlapping generations (Adkison 1995). The coincidence of such conditions may be uncommon in Pacific salmon populations. Localized adaptation needs still further conditions, such that selective regimes are not too localized and that straying rates are neither too low nor too high (Adkison 1995).

On the other hand, conserving the adaptive responses of salmon populations in the long term calls for assuming differences by geographic location unless otherwise demonstrated (Riddell 1993). The loss of a locally adapted salmon population from a watershed would result in immediate and lasting loss in production, and in lowered productivity (Riddell 1993). Loss of random genetic diversity may prevent salmon from adapting to rapid habitat changes brought about by human activities and natural events such as global warming (Adkison 1995). In the final analysis, definitions of the "spawning aggregate" are likely to be common sense compromises between the biological objective of protecting genetic diversity, and the objective of providing reasonable access to the salmon resources for sustainable use.

Stock identification: The process of assigning salmon landings to spawning locality (Grant, Milner et al. 1980; Marshall, Bernard et al. 1987).

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APPENDIX

Table A -1. Principles and criteria for sustainable salmon fishing

Principle I. Protect wild salmon and their habitat in order to maintain resource productivity.

Criteria for Principle I

I. 1. Salmon spawning, rearing, and migratory habitats are protected.

I. 1. A. Salmon stocks and habitat are not perturbed beyond natural boundaries of variation.
I. 1. B. Scientific assessment of possible adverse ecological effects of habitat alteration proceed prior to approval of proposed alteration of salmon habitat.
I. 1 .C. Adverse environmental impacts on wild salmon and their habitats are assessed and corrected when appropriate.
I. 1. D. All essential salmon habitats in marine, estuarine and freshwater ecosystems are protected.

These include:

i. Spawning beds
ii. Freshwater rearing areas
iii. Estuarine/near-shore rearing areas
iv. Offshore rearing areas
v. Riparian and coastal zones

I. 1. E. Salmon habitat is protected on a watershed basis.

I. 2. Salmon are protected within spawning, rearing, and migratory habitats.

I. 3. Collateral mortality resulting from habitat loss is understood and communicated to affected user groups.

Principle II. Maintain escapements within ranges necessary to conserve and protect potential salmon production and maintaining normal ecosystem functioning .

Criteria for Principle II

II. 1. The temporal and geographic magnitudes of spawning escapements are measured.

II. 2. Escapement goals are established in a manner consistent with sustained yield.

II. 3. Escapement goal ranges incorporate the uncertainty associated with measurement techniques, observed variability in the population measured, and the varying abundance within related sub stocks of the population measured.

II. 4. Escapement goals are achieved in a manner consistent with appropriate geographic and temporal distribution of spawners.

II. 5. Sources and locations of fishing mortality are understood.

II. 6. Escapements are achieved in a manner consistent with protection of non-target stocks or species.

II. 7. The phenotypic and genetic characteristics of escapement are understood.

II. 8. The role of salmon in normal ecosystem functioning (fish and wildlife and their habitat) is understood.

II. 9. The population trends of the salmon and allied species are understood.

Principle III. Harvest salmon in a manner consistent with the degree of knowledge and uncertainty regarding the status and biology of the resource

Criteria for Principle III

III. 1. A precautionary approach is applied to the regulation of activities that alter essential habitat.

III. 2. A precautionary approach is applied to the regulation of harvest and other consumptive uses of salmon.

III. 3. Conservation and management decisions for fisheries take into account the best available information, including environmental, economic, social, and resource use factors.

III. 4. The best available scientific information on the status of populations and the condition of their habitats is routinely updated and peer reviewed.

III. 5. Data collections and research are undertaken in order to improve scientific and technical knowledge of fisheries including their interactions with the ecosystem.

III. 6. Proposals for salmon fisheries development or expansion document resource assessments and other criteria required for sustainable management.

Principle IV. Establish and apply an effective salmon management system to control human activities that affect salmon

Criteria for Principle IV

IV. 1. Salmon management objectives appropriate to scale and intensity of use are in place.

IV. 2. Management objectives subject to periodic review are provided in the forms of the harvest management plans, harvest management strategies, guiding principles, and policies for managing mixed stocks, fish disease, and genetics.

IV. 3. The effectiveness of habitat protection laws and regulations intended to sustain productivity of salmon habitats are regularly evaluated and documented.

IV. 4. Government has an open process for objectively evaluating the effectiveness of fishery management actions.

IV. 5. Management has the means to separate biological and allocation issues.

IV. 6. Feedback loops are consistently applied, using post-season management action indicators (escapement habitat maintenance within current regulations, etc.), to verify that the management actions sustained salmon populations, fisheries and habitat. Where deficiencies are documented, actions are taken to resolve them.

IV. 7. Fisheries management implementation and outcomes are consistent with Board regulations. Board regulations are consistent with Alaska statutes. As an example, subsistence needs receive priority called for by statute.

IV. 8. Management acts in a timely and adaptive fashion to implement objectives on the basis of best available scientific information.

IV. 9. Management agency has clear authority (in statute and regulation) to control human-induced sources of salmon mortality, including mortality due to habitat loss (a form of collateral mortality).

IV. 10. Management takes into account the consequences of artificial propagation of salmon on natural stocks.

IV. 11. Management incorporates appropriate procedures for effective compliance, monitoring, control, surveillance and enforcement.

IV. 12 The transboundary nature of aquatic ecosystems is recognized by encouraging multilateral cooperation in research and management.

IV. 13. For transboundary stocks appropriate procedures for effective compliance, monitoring, control, and surveillance are coordinated with those of other states or agencies.

IV. 14. Effective joint assessment and management arrangements are in place for stocks that cross jurisdictional boundaries.

IV. 15. Management has access to the resources necessary for collection and dissemination of the information and data necessary to carry out management activities.

IV. 16. Government provides adequate staff and budget for the research, management and enforcement activities necessary to implement the sustainable fisheries management principles.

Principle V. Maintain public support and involvement for sustained use and protection of salmon resources

Criteria for Principle V

V. 1. A governmental process incorporates appropriate mechanisms for resolution of disputes.

V. 2. An open and fair public involvement process addresses management and allocation decisions.

V. 3. A governmental process provides an allocation of the conservation burden for salmon across all consumptive user groups.

V. 4. A governmental process provides adequately funded public information and education programs for the public concerning salmon habitat requirements, salmon habitat threats, the value of salmon and habitat to public and ecosystem, natural variability and population dynamics, value of salmon to other fish and wildlife, current status of Alaska fish stocks and fisheries, Board of Fisheries process.

V. 5. Management provides for dissemination of results to all interested parties in a timely fashion.

V. 6. Management promotes understanding of the proportion of mortality inflicted on each stock by each consumptive user group.

Table A - 2. Principles for the Conservation of Wild Living Resources (Mangel et al. 1996)

Principle I. Maintenance of healthy populations of wild living resources in perpetuity is inconsistent with unlimited growth of human consumption of and demand for those resources.

Principle II. The goal of conservation should be to secure present and future options by maintaining biological diversity at genetic, species, population and ecosystem levels; as a general rule neither the resource nor any other components of the ecosystem should be perturbed beyond natural boundaries of variation.

Principle III. Assessment of the possible ecological and effects of resource use should precede both proposed use and proposed restriction or expansion of ongoing use of a resource.

Principle IV. Regulation of the use of living resources must be based on understanding the structure and dynamics of the ecosystem of which the resource is a part and must take into account the ecological and sociological influences that directly and indirectly affect resource use.

Principle V. The full range of knowledge and skills from the natural and social sciences must be brought to bear on conservation problems.

Principle VI. Effective conservation requires understanding and taking account of the motives, interests, and values of all users and stakeholders, but not by simply averaging their positions.

Principle VII. Effective conservation requires communication that is interactive, reciprocal, and continuous.

Table A - 3. The Marine Stewardship Council Draft Principles for Sustainable Fishing (MSC 1996)

- Principle 1: The fishery shall be conducted in a manner consistent with international, national and local laws and standards, and in compliance with the MSC Principles and Criteria.

- Principle 2: The fishery should secure present and future options by maintaining biological diversity at genetic, species, population and ecosystem levels, accepting that fisheries intrinsically affect the level of the stocks they exploit; nevertheless, as a general rule the ecosystem should not be perturbed by fishing beyond the natural boundaries of variation.

- Principle 3: The fishery is subject to an effective management system that incorporates clear long-term objectives consistent with these principles and criteria, including stock rebuilding, and a management plan that is subject to periodic performance evaluation.

- Principle 4: The fishery should be conducted in a manner that encourages efficient use of available resources, avoids waste, promotes economic viability, and provides a wide range of environmental and social benefits.

- Principle 5: The fishery should observe the rights and long term interests of people dependent on fishing for food and livelihood in a manner consistent with ecological sustainability.

Table A - 4. The Marine Stewardship Council Draft Principle and Criteria on Sustainable Fishery Management (MSC 1996).

Principle: The fishery is subject to an effective management system that incorporates clear long-term objectives consistent with these principles and criteria, including stock rebuilding, and a management plan that is subject to periodic performance evaluation.

Criteria

1. The management decision-making process is transparent and involves consultation with all interested and affected parties so as to consider all relevant information, including local knowledge.

Criteria regarding the management system

2.1 Has clear long-term objectives consistent with these principles and criteria
2.2 Incorporates a written management plan that is appropriate to the scale and intensity of the fishery, that reflects specific objectives, incorporates operational criteria, contains procedures for implementation and a process for evaluating performance.
2.3 Acts in a timely and adaptive fashion on the basis of the best available scientific advice.
2.4 Requires a periodic assessment of the biological status of the resource and impacts of the fishery.
2.5 Specifies management measures and strategies (e.g. effort or catch control, closed seasons and areas, etc.) that control the degree of exploitation of the resource.
2.6 Implements the precautionary approach so as to ensure that established limits to exploitation are not exceeded and specifies emergency actions to be taken in such an event. The precautionary approach is defined in article 6 and Annex II of the UN Agreement on Straddling Fish Stocks & Highly Migratory Fish Stocks, Article 7.5 of the FAO Code of Conduct for Responsible Fisheries, and other relevant documents.
2.8 Provides an appropriate set of economic and social incentives which lead to sustainable fishing and which address overcapitalization of the fishery.
2.9 Incorporates appropriate procedures for effective compliance, monitoring, control, surveillance and enforcement.

2.10 Provides for the recovery and rebuilding of depleted fish populations to specified stock sizes within specified time frames.
2.11 Takes into account the impacts of other human and environmental influences on the ecosystem.
2.12 Incorporates a research plan that is appropriate to the scale and intensity of the fishery that addresses the immediate needs of management and provides for the dissemination of research results to all interested parties in a timely fashion.
2.13 Maintains strict operational codes regarding the discarding of fishing gear, the recovery of lost gear, and pollution from fishing operations.
2.14 Provides an appropriate mechanism to collect the information and data necessary to carry out management activities.
2.15 Incorporates an appropriate mechanism for the resolution of disputes.

Table A -5. FAO Code of Conduct for Responsible Fisheries, Article 6 - General Principles

6.1 States and users of aquatic resources should conserve aquatic ecosystems. The right to fish carries with it the obligation to do so in a responsible manner so as to ensure effective conservation and management of the living aquatic resources.

6.2 Fisheries management should promote the maintenance of the quality, diversity and availability of fishery resources in sufficient quantities for present and future generations in the context of food security, poverty alleviation and sustainable development. Management measures should not only ensure the conservation of target species but also of species belonging to the same ecosystem or associated with or dependent upon the target species.

6.3 States should prevent overfishing and excess fishing capacity and should implement management measures to ensure that fishing effort is commensurate with the productive capacity of the fishery resources and their sustainable utilization. States should take measures to rehabilitate populations as far as possible and when appropriate.

6.4 Conservation and management decisions for fisheries should be based on the best scientific evidence available, also taking into account traditional knowledge of the resources and their habitat, as well as relevant environmental, economic, and social factors. States should assign priority to undertake research and data collection in order to improve scientific and technical knowledge of fisheries including their interaction with the ecosystem. In recognizing the transboundary nature of many aquatic ecosystems, States should encourage bilateral and multilateral cooperation in research, as appropriate.

6.5 States and subregional and regional fisheries management organizations should apply a precautionary approach widely to conservation, management and exploitation of living resources in order to protect them and preserve the aquatic environment, taking account of the best scientific information available. The absence of adequate scientific information should not be used as a reason for postponing or failing to take measures to conserve target species, associated or dependent species and non-target species and their environment.

6.6 Selective environmentally safe fishing gear and practices should be further developed and applied, to the extent practicable, in order to maintain biodiversity and to conserve the population structure and aquatic ecosystems and protect fish quality. Where proper selective and environmentally safe fishing gear and practices exist, they should be recognized and accorded a priority in establishing conservation and management measures for fisheries. States and users of aquatic ecosystems should minimize waste, catch of non-target species, both fish and non-fish species, and impacts on associated or dependent species.

6.7 The harvesting, handling, processing and distribution of fish and fishery products should be carried out in a manner which will maintain the nutritional value, quality and safety of the products, reduce waste, and minimize negative impacts on the environment.

6.8 All critical fisheries habitats in marine and freshwater ecosystems, such as wetlands, mangroves, reefs, lagoons, nursery and spawning areas, should be protected and rehabilitated as far as possible and where necessary. Particular effort should be made to protect such habitats from destruction, degradation and pollution and other significant impacts resulting from human activities that threaten the health and viability of the fishery resources.

6.10 Within their respective competences and in accordance with international law, including within the framework of subregional or regional fisheries conservation and management organizations or arrangements, States should ensure compliance with and enforcement of conservation and management measures and establish effective mechanisms, as appropriate, to monitor and control the activities of fishing vessels and fishing support vessels.

Table A - 6. FAO Code of Conduct for Responsible Fisheries, Article 7
Fisheries Management

7.1.1 States and all those engaged in fisheries management should, through an appropriate policy, legal and institutional framework, adopt measures for the long-term conservation and sustainable use of fisheries resources. Conservation and management measures, whether at local national, subregional or regional levels, should be based on the best scientific advice available and be designed to ensure the long-term sustainability of fishery resources at levels which promote the objective of their optimum utilization and maintain their availability for present and future generations; short-term considerations should not compromise these objectives.

7.2 Management objectives

7.2.1 Recognizing that long-term sustainable use of fisheries resources is the overriding objective of conservation and management, States and subregional or regional fisheries management organizations and arrangements should, inter alia, adopt appropriate measures, based on the best scientific evidence available, which are designed to maintain or restore stocks at levels capable of producing maximum sustained yield, as qualified by relevant environmental and economic factors, including the special requirements of developing countries.

7.2.2 Such measures should provide inter alia that:

a) excess fishing capacity is avoided and exploitation of the stocks remain economically viable;

b) the economic condition under which fishing industries operate promote responsible fisheries;

c) the interests of fishers, including those engaged in subsistence, small scale and artisanal fisheries, are taken into account;

d) biodiversity of aquatic habitats and ecosystems is conserved and endangered species are protected;

e) depleted stocks are allowed to recover or, where appropriate, are actively restored;

f) adverse environmental impacts on the resources from human activities are assessed and where appropriate corrected; and

g) pollution, waste, discards, catch by catch by lost or abandoned gear, catch of non-target species, both fish and non-fish species impacts on associated or dependent species are minimized, through measures including, to the extent practicable, the development and use of selective, environmentally safe and cost-effective fishing gear and techniques.

7.2.3 States should assess the impacts of environmental factors on target species stocks and species belonging to the same ecosystem or associated with or dependent upon the target stocks, and assess the relationship among the populations in the ecosystem.

Table A - 7. Conservation Principles for Fisheries Management (Olver, Shuter et al. 1995).

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1. Aquatic ecosystems should be managed to ensure long-term sustainablity of native fish stocks

2. The sustainability of a fish stock requires

   - protection of the specific physical and chemical habitats utilized by the individual members of that stock
   - maintenance of its supporting native community

3. Vulnerable, threatened, and endangered species must be rigidly protected from all anthropogenic stresses

4. Exploitation of populations or stocks undergoing rehabilitation will delay, and may preclude, full rehabilitation

5. Harvest must not exceed the regeneration rate of a population or its individual stocks

6. Direct exploitation of spawning aggregations increases the risk to sustainability to fish stocks (Note that intensively managed and researched salmon fisheries are specifically excluded from this statement.)

Table A - 8 The American Fisheries Society North American Fisheries Policy Excerpts of key points from the published draft (Starnes, Jiminez et al. 1995).

1. Protection of ecosystems, communities, and genetic diversity

- The American Fisheries Society promotes the well-being of North American fishes throughout their geographic ranges and promotes natural genetic variability within and among populations. North American ecosystems, biological communities, habitats, and their genetic and ecological diversity should be maintained, restored, and enhanced where possible.

2. Manage for sustainability

- Commercial fisheries should be administered to ensure the long term sustainability of populations of aquatic resources (including non-target , bycatch species) and their habitats.

- Sportsfisheries should also be administered to provide long-term sustainability of aquatic populations and habitats while at the same time ensuring a diversity of recreational opportunities to a wide range of public interests (including consumptive and nonconsumptive as diverse as opportunities for religious and subsistence uses).

- When conflicts arise among user interests, the sustainability of the aquatic resources involved should be considered foremost. If requirements for sustainability can be met, allocation should be considered to meet diverse public demands.

3. Cooperation and coordination for protection of migratory, straddling fish stocks

- Any aquatic resources exploited for recreational or commercial harvest managed by two or more jurisdictions (i.e., federal, state, provincial, or tribal) or nations should be studied and managed as common units through agreements between the parties concerned. Any transboundary aquatic resources not now subject to study and management should be brought under agreement as soon as possible.

- Agencies are responsible for preserving biodiversity concomitant with maintaining long-term sustainability of utilized resources, and should coordinate their activities through an ecological approach that includes habitat and watershed perspectives, community interactions, and genetic and ecological processes. Critical to this effort is that managers should communicate their needs, coordinate their activities, and share natural resource data.

4. Information is the key to successful sustainable management

- Fishery administrators need complete and accurate information on the status of aquatic resources. This information will be used in balancing aquatic resource and human needs.

- The management of aquatic species and their habitats requires continuous updating of scientific information on the status of populations and the condition of their habitats. For all species this includes monitoring of utilized populations. Data should be generated by a variety of disciplines and research interests and should be validated by peer review and scientific replication.

5. Protect the fishing industries while protecting the fish

- North American fisheries are an important part of the food industry that supplies a great variety of food products for human and domestic animal consumption. Management of these fisheries must be in the best interests of the fisheries and future generations of users and requires conservation of resources to promote the economic well-being of the consumer.

6. Minimize unintended impacts of fishing

- Commercial fisheries should be conducted to the greatest extent possible with minimal bycatch, and fishing gear should not damage the environment.

7. Management of habitat is necessarily an ecologically oriented activity

- Management manipulation of habitat should include integrating biotic, chemical and physical processes within the management framework. Needs of all components of the ecosystem including all life stages of involved species, should be considered during planning, implementing, and monitoring of habitat management activities.

Table A - 9. Constant harvest rate vs. fixed escapement harvest policies

Comparison of constant harvest rate to fixed escapement harvest policies under management error for Pacific salmon. Findings and recommendations of a simulation study. (Eggers 1993).

- The precision with which harvest managers meet harvest objectives determines the long-term yield from the salmon fishery for both policies.
- The precision with which harvest managers meet harvest objectives determines the interannual stability of the long-term yield from the salmon fishery for both policies.
- An escapement goal range policy may be substituted for the constant escapement goal policy without substantially lowering long-term average catch.
- The escapement goal range policy provides managers with the flexibility to protect weak stocks in mixed stock fisheries.
- Constant escapement goal harvest policy means higher annual yield from the salmon fishery than is achieved by constant harvest rate policy at any given level of harvest management error when the number of salmon in the escapement is near the number that produces maximum sustained yield.
- Constant escapement goal harvest policy means more interannual stability in yield from the salmon fishery than is achieved by constant harvest rate policy at any given level of harvest management error when escapements in the vicinity of those producing maximum sustained yield are provided.
- Constant escapement policy keeps yield indicators at moderate to high levels over a much broader range of management errors and management objectives than the constant harvest rate policy.
- Constant harvest rate management is very risky for Pacific salmon under situations of high management error such as are likely to occur under salmon management programs with objectives such as regularly timed openings and guideline harvest levels.

Table A - 10. Tongass National Forest impacts of operations on fish habitat. Findings and recommendations of a U.S. Forest Service Report (USFS 1995).

1) the level of logging and associated roads in a watershed is directly related to the level of degradation of fish habitat, with the greatest risk resulting from roads;
2) despite best management practices (called BMPs) to minimize non-point source pollution of fish streams from roads, rock quarries, and harvest units, as well as 100 - foot or wider “no harvest” buffers on all anadromous streams and all tributaries flowing directly into them, additional protection of fish habitat is needed to better assure that timber harvest and associated roads are compatible with maintaining high-quality fish habitat and long-term conservation of fish stocks;
3) the following improvements were needed to fully protect fish habitat and adopted into the newly revised Tongass Forest Plan:

A) riparian no-harvest buffers on fish streams should be as wide as the greater of the height of one site-potential tree, the riparian floodplain and contiguous wetland fens; an additional streamside management zone as wide as the tallest tree is also needed to ensure the no harvest buffer is windfirm over the long term;
B) headwater (non-fish) streams need more protection to maintain their large woody debris, which stores sediment and reduces sediment flowing down into fish streams and also provides LWD to the fish streams;
C) BMPs to protect water quality should be more fully implemented and monitored to ensure compliance;

4) although the following improvements were needed to fully protect fish habitat they were not adopted into the newly revised Tongass Forest Plan:

A) watershed analyses are an important tool to design the development of a watershed to minimize the adverse effects on fish habitat;
B) quantifiable and measurable salmon production objectives should be developed for watersheds with timber harvest and other disturbances;
C) monitoring, the effectiveness of BMPs and buffers in protecting fish habitat must be accelerated. Repeatable, long-term baseline research measurements should be established on some fish streams to document changes in habitat conditions an salmon productivity; and
D) salmon habitat capability models should be developed to quantify natural productivity of each watershed and to predict reduction in this productivity as a result of land and water developments.

Table A - 11. Criteria relevant to protection of essential salmon habitat.
Source: The National Marine Fisheries Service (Murphy 1995).

1) Buffers along fish streams must be wide enough to fully protect channel morphology, floodplains, riparian vegetation, long-term sources of large woody debris, LWD, and the long-term integrity and viability of the buffer itself; in coastal Alaska and the Pacific Northwest. This requires a no-harvest buffer greater than the height of one site-potential tree, typically > 100 feet - 140 feet.

2) buffers on fish streams alone do not maintain fish habitat; also need to protect hydrologically sensitive areas identified in a watershed analysis, headwater channels to protect LWD and water quality and temperature; and BMPs to control non-point source pollution;

3) timber harvest should mimic natural disturbances, which in Alaska coastal forests means small windthrow events that create natural gaps in the tree overstory canopy;

4) restore fish habitat by obliterating or stabilizing roads, correcting blockages to fish passage from undersized and improperly constructed and maintained culverts, and controlling all erosion;

Table A - 12. N R C / CPMPNAS fishery management principles.

Synopsis of fishery management principles, findings and recommendations of the Committee on Protection and Management of Pacific Northwest Anadromous Salmonids, Board of Environmental Science and Toxicology, Commission on Life Science, National Research Council, National Academy of Sciences (NRC 1996). Note that the language in the NRC report has been paraphrased.

Principles

- Pacific salmon populations are organized into diverse, spatially distributed spawning populations that exhibit genetic diversity, maximal use of available habitat, and potential for increasing production from natural spawners
- The exploitation rate that can be sustained by salmon is a function of the productivities in each stage of the life cycle of the population
- Mortality due to catch is not independent of other sources of mortality
- Mortality due to catch is not an alternative for other, uncontrollable sources of mortality
- The number of salmon available to be harvested (from a stock) is determined by brood-year survival to the point of fishing, and the number in the desired spawning stock size (escapement objective)
- As but one part of the dynamic evolutionary processes in the ecosystems in which they occur, the production of salmon is variable and dependent upon the condition of the ecosystem's communities and habitats
- The same salmon catches can be achieved by low fishing rates applied to highly abundant stocks or by fishing at high rates on less abundant stocks
- Salmon management systems must acknowledge and take into account the limitations imposed by uncertainty about the abundances of salmon available for harvest because natural variation among salmon populations through time makes the production from each brood year highly uncertain
- Sustainability of salmon in the Pacific Northwest is inextricably linked to economic development and societal values

Findings

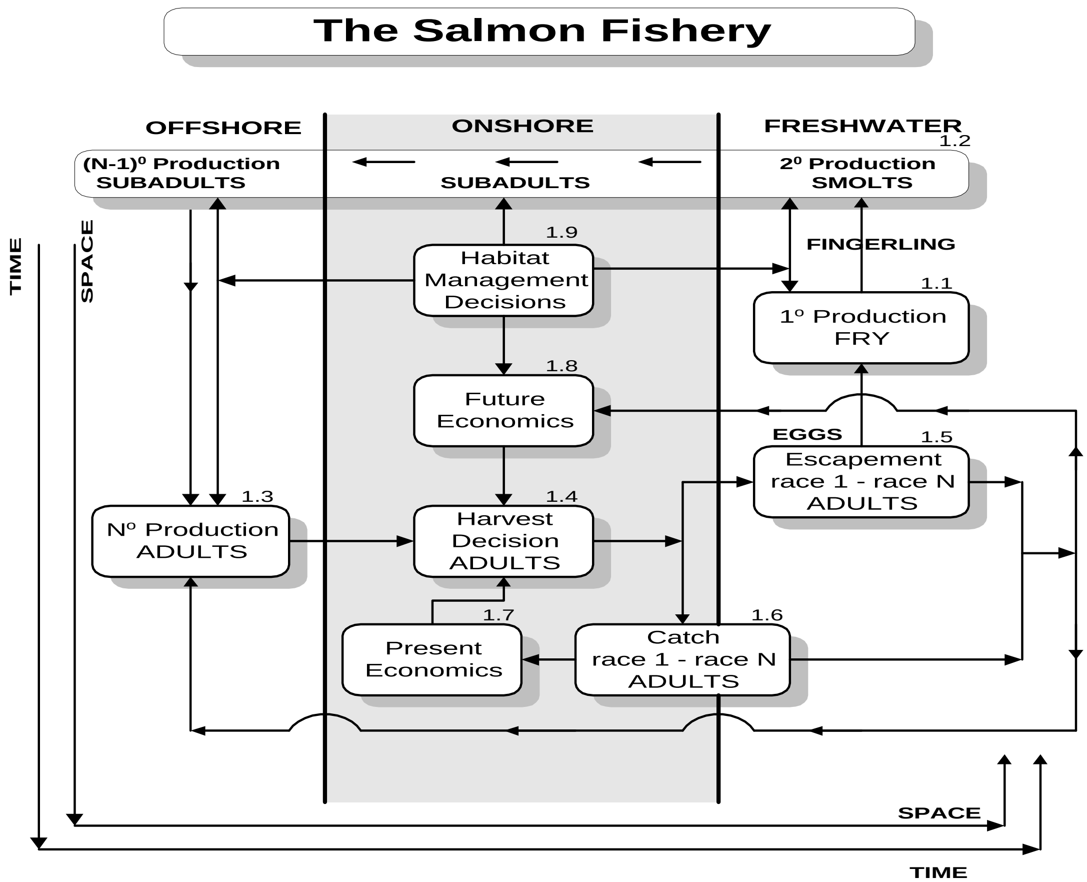
- Fishing must be managed on the basis of total fishing mortalities (catch plus incidental fishing mortalities) and operate at sustainable exploitation rates
- Management of salmon should allow for separate management regimes for strong and depleted populations and metapopulations and the genetic structure of those groups when possible
- The management cycle for (salmon) fisheries involves four activities: stock assessment, development of management plans, conducting fisheries, and evaluation
- Critical elements of the management cycle for fisheries are sound biological advice, explicit and assessable biological, social, economic and other management objectives, an institutional process for developing management plans, control of fisheries, and accountability in achieving management objectives
- The resource base necessary to sustain salmon production consists of genetic diversity within and among breeding populations and the habitat necessary to complete the life cycle

Recommendations

- A stronger societal commitment to the biological resource base must be established if salmon are to be sustained
- Establish minimum safe levels of spawning escapements to reduce the risk of continued loss of salmon populations and production
- Manage salmon harvests to obtain minimum safe levels of spawning escapements and increased diversity within and between local breeding populations

Principles and Criteria for Sustainable Salmon Management

A Contribution to the Development of a Salmon Fishery Evaluation Framework for the State of Alaska



FINAL REPORT

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